EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION

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RADIODIAGNOSIS

BY

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DAYANAND MEDICAL COLLEGE AND HOSPITAL
LUDHIANA,
(MAY, 2021)

DECLARATION

I declare that the thesis entitled "**EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION"** has been prepared by me under the guidance **Dr. Chandan Kakkar, Associate Professor,** department of Radio-Diagnosis, Dayanand Medical College and Hospital, Ludhiana. No part of this thesis has formed the basis for the award of any degree previously.

_____

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CERTIFICATE

I certify that **Dr. Aditi Gupta** has prepared her thesis entitled, **"EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION"** for the award of M.D. degree of Baba Farid University of Health Sciences under our guidance. She has carried out the work at the Department of Radio diagnosis, Dayanand Medical College and Hospital, Ludhiana.

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Dedicated

To

My Family and

Respected

Teachers

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Dr. Aditi Gupta

ABBREVIATIONS

C	Communited
L	Linear
U/L	Unilateral
B/L	Bilateral
D	Displacement
AW	Anterior wall
PW	Posterior wall
AC	Anterior column
PC	Posterior column
QP	Quadrilateral plate
S.I	Surface irregularity
EXT	Extension
IB	Iliac bone
S	Sacrum
R	Rami
FM	Femur
IABF	Intra-articular bony fragments
JSI	Joint surface irregularity
FE	Fracture extension
ASS	Associated fractures
VRT	Volume rendering technique
MPR	Multiplanar reformat
A	+
BA	+++

+	Present
-	Absent
RSA	Road side accident
M	Male
F	Female
CT	Computed tomography
Sr.No.	Serial number
+	Appreciated
+++	Better Appreciated

ABSTRACT

Introduction: The most widely used acetabular fracture classification system is Judet and Letournel. Accurate categorization of acetabular fractures is challenging because of the complex three-dimensional (3D) anatomy of the pelvis. CT provides information on the extent of the fracture and complements conventional radiography in ascertaining the spatial arrangement of the fracture fragments. Also, MPR and VRT reconstructions of CT data have been used as an aid to understand complex fracture patterns. By reviewing a VRT image, the surgeon can decide whether or not to operate and which approach to use.

Aim of Study: To evaluate the role of MDCT in assessment of acetabular fractures and correlate MPR vs VRT MDCT findings.

Materials & Methods: The study will be conducted over a period of one year. In this prospective study, CT was performed on 50 patients. Axial, saggital and coronal images were obtained which were then reconstructed into volume rendered images (VRT).

Results: The most common dislocation of the femoral head associated with pelvic trauma was posterior. T- type fractures in 75% of cases and both column fractures in 80% cases were better classified on VRT. Simpler fractures like the transverse and displaced fractures of anterior and posterior walls were better classified on VRT images. Simple and undisplaced fractures of the anterior and posterior walls which were better classified on MPR. Intra-articular bony fragments and associated pelvic fractures were best seen on MPR images. The fracture extension lines and displacements were best seen on VRT images.

CONCLUSION: CT is superior to radiographs in evaluating acetabular fractures. Associated fractures of pelvic bones, and in the detection of intra-articular fragments. CT displays better anatomy of the acetabulum in the axial plane i.e MPR images with VRT better in complex and displaced fractures.

Keywords: CT-Computed Tomography, MPR- Mutiplanar Reformat, VRT- Volume rendering Technique

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INTRODUCTION

Pelvic fractures are common among patients that sustain multiple injuries. Initial radiographic evaluation in trauma patients is frequently suboptimal and limited to antero-posterior (AP) views. Computed tomography (CT) has become a necessary adjunctive study that, compared with conventional radiography, provides an improved demonstration of intra-articular fragments, joint surface incongruities, and femoral head and sacral fractures.[1]

The use of multiplanar two- and three- dimensional CT images has proved helpful for the detailed analysis of acetabular fractures. A thorough understanding of the fracture pattern and the spatial relationships of the fracture fragments is needed for surgical planning. Newer surgical techniques and instrumentation permit improved internal fixation of the acetabular fracture, resulting in a better long-term outcome.[2]

Acetabular fractures constitute between 20% and 25% of all pelvic fractures in adults. These fractures have a high association with injuries to the genitourinary system and vascular structures. Radiographs with oblique views are often difficult to evaluate when trying to determine the extent of involvement of presurgical planning.[3]

CT is the modality of choice for evaluating these injuries. Axial images should be performed with contiguous slices no thicker than 3mm. Sagittal and coronal reconstructions and three-dimensional images are often helpful to conceptualize the fracture pattern before surgery. [4]

Conventional radiographic projections especially designed views although very helpful often cannot provide sufficient information on these fractures. Computed tomography conversely displays anatomy in the axial plane thereby provides missing pieces of information and greatly facilitating accurate classification of injuries. [5]

CT helps delineate the extent and configuration of fractures of the acetabulum as the acetabular fractures and fracture-dislocations of the hip joint are frequently complex and routine radiographs do not easily demonstrate the precise pathological anatomy. Intraarticular bony fragments, joint space incongruity, femoral head fractures, and other unsuspected fractures may only be revealed by CT examination.[6]

The transverse plane of CT is superior for the estimation of rotation of the columns and especially for the study of the posterior acetabular margins, the size and displacement of which are often poorly visible on conventional radiographs. Moreover, conventional views are difficult to assess because of their often poor quality in traumatized patients.[7]

Role of conventional radiography- Plain X-rays provide a starting point for preliminary investigation however has become less important since the advent of CT. It is still useful in peripheral areas where CT is not available. In addition to the standard AP view of the pelvis for assessment of pelvic trauma 45-degree oblique view and iliac oblique view are also sometimes taken to assess and delineate the extent of trauma. Inlet and outlet views have been shown to provide useful information about the integrity of the sacrum and sacroiliac joint. These views also provide only means whereby the spatial relationship of bones of the pelvic ring can be assessed.[8]

MDCT and its use in studying acetabular fractures- MDCT is more sensitive and specific in imaging acetabular trauma than radiography. If MDCT is performed, radiography in the acute phase is not necessary to detect or to evaluate an acetabular fracture. CT is useful not only for detecting injury but also for characterizing injuries better than radiography. The degree of comminution, the rotation or displacement of fracture fragments, possible impaction of the joint surface, femoral head fractures, associated soft tissue injury, haemorrhage, and the relation of the sciatic nerve to the fracture fragments are all better evaluated with CT. Because an acetabular fracture may course from

the obturator ring cranial into the iliac wing, imaging of such injuries with CT should include the area from above the iliac crests to below the inferior pubic rami. [9]

CT findings- CT has been routinely performed preoperatively on patients with acetabular fractures. On axial CT slices, the main direction of the fracture line through the acetabular roof will usually be in one of three typical planes – sagittal for transverse fractures, coronal for column fractures, or oblique for wall fractures. The fracture extent and direction in the cranio-caudal direction can be evaluated on axial images. The inferior pubic ramus should also be evaluated for fracture. The hip joint and pulvinar should be carefully reviewed on thin slices for small intra-articular bone fragments, especially in cases of posterior wall fractures with hip dislocations. Computed tomography is more sensitive than plain radiography in detecting pelvic fractures involving the sacrum, quadrilateral surface, acetabular roof, and posterior acetabular lip. Also abnormalities of joint space, primary loose bone fragments are detected more often by CT.

The use of MPR images, where particularly the parasagittal images can be tilted and rotated slightly for better coverage of the Para-acetabular skeleton, facilitates the evaluation of fracture extent and displaced wall fragments. The MPR images are also indispensable for evaluating the status of the articular surface. The 3-D images should be evaluated in real-time to assess the medial and lateral surfaces of the fractured hemi pelvis. The reconstructed 3-D images can recreate the obliquity in the Judet images and show the pelvis in any viewing.[10]
3D CT provides the best and most easily interpreted overall assessment of fractures. Although 3D CT is a valuable addition to the imaging of acetabular fractures, it is not a substitute for analysis of the axial CT images.[11]
In the present study, the significance of computed tomography in diagnostic evaluation and management of the pelvic trauma patients was assessed, and a comparison of multiplanar reformat (MPR) with

volumetric rendering techniques (VRT) in fracture detection for diagnosis and management of acetabular fractures were compared.

ANATOMY

The pelvis is a complex three-dimensional (3D) bone that, because of overlap with itself and with the femur, has surfaces that are not easily visible on standard frontal and lateral projections. Fracture nomenclature is complicated and not intuitive. Fractures are described relative to the orientation of the acetabulum viewed en face from the lateral side, whereas, in the anatomic position, the acetabulum is tilted inferiorly and anteriorly, making its appearance at radiography and planar computed tomography (CT) non-intuitive relative to the nomenclature.[12]

For example, although the superior pubic ramus is superior, when viewing the acetabulum en face it is anterior. Furthermore, transverse fractures of the acetabulum are predominantly transverse in the acetabular plane but are sagittal oblique (with the medial aspect superior to the lateral aspect) in the anatomic plane.

Fracture nomenclature is also not intuitive. For example, transverse acetabular fractures traverse both columns but are not classified as "associated both columns" fractures; the term associated both column fracture is reserved for a fracture pattern in which the acetabular articular surface is no longer continuous with the intact Ilium and is completely separate from the sciatic buttress. We primarily focus on classifying fractures with surface-rendered 3D multidetector CT (MDCT) images.[13]

Anatomy of the Acetabulum - The adult acetabulum contains components of the Ilium, ischium, and pubis, which together form the in nominate bone. The acetabulum contains anterior and posterior walls (or rims) but is open inferiorly to the acetabular notch. There is an upside-down U-shaped hyaline cartilage–covered articular surface that contacts the femoral head. The central non-articular portion of the "U" is termed the cotyloid fossa and contains fatty pulvinar and the ligament teres. The flat medial surface of the acetabulum that faces the

pelvic organs is named the quadrilateral plate or surface. The sciatic buttress lies along the superior postero-medial portion of the innominate bone, adjacent to the sacroiliac joint.

When an orthopedic surgeon fixes an acetabular fracture, the fracture is built back to this portion of the intact Ilium. The acetabulum articulates with the femoral head, coupling the axial and appendicular skeletons by way of the sciatic buttress. The sciatic buttress is the confluence of the anterior and posterior columns of the acetabulum. Together, the columns form a lowercase lambda (l) shape, with a longer anterior column and a shorter posterior column. Anterior and posterior column support of the acetabulum is essential when considering the internal fixation of acetabular fractures.

The anterior column includes the anterior border of the iliac wing, the pelvic brim, the anterior superior iliac spine, the anterior inferior iliac spine, the anterior wall of the acetabulum, and the superior pubic ramus.
The posterior column includes only the ischial portion of the innominate bone, including the greater and lesser sciatic notches, the posterior wall of the acetabulum, and the ischial tuberosity. The columns are bridged inferiorly by the ischiopubic ramus, which is composed of the inferior pubic ramus and the inferior ischial ramus.

Systems of Acetabular Fracture Classification- There are two classic morphologic classification systems for acetabular fractures: the Judet and Letournel system (4) and the Orthopedic Trauma Association (OTA)/Arbeitsgemeinschaft für Osteosynthesefragen (AO) scheme.
The four lines that are fundamental to Judet and Letournel's approach are the anterior and posterior acetabular rims (or walls) and the iliopectineal and ilioischial lines.
In the Judet and Letournel system, there are 10 fractures or fracture combinations that separate walls from the acetabulum and columns

from the sciatic buttress or that are transversely oriented through the acetabulum.

Fractures are classified into five elementary fractures, which divide the innominate bone and acetabulum into two major fragments, and five associated fractures, which divide the innominate bone and acetabulum into three major fragments.

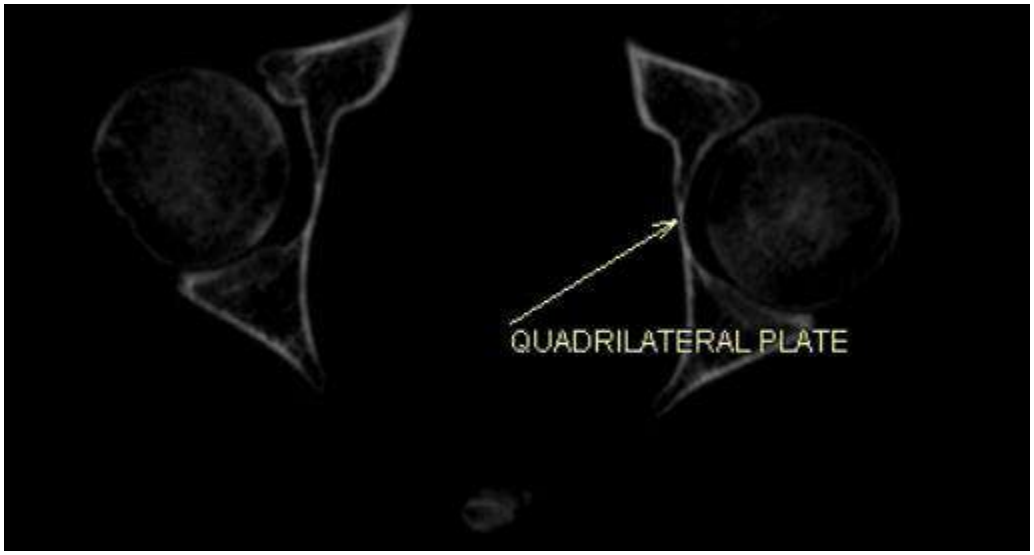
The five elementary fracture types are

1. Posterior Wall, Anterior Wall,
2. Posterior Column,
3. Anterior Column, And
4. Transverse.

The five associated fracture types are combinations or partial combinations of the elementary fractures and include

1. Transverse With Posterior Wall,
2. Posterior Column With Posterior Wall,
3. T-Shaped,
4. Anterior Column Or Wall With Posterior Hemi transverse, And
5. Associated Both Column fractures

Despite the presence of 10 fracture types, five fractures (posterior wall, transverse, transverse with posterior wall, both column, and T-shaped) account for approximately 80% of all acetabular fractures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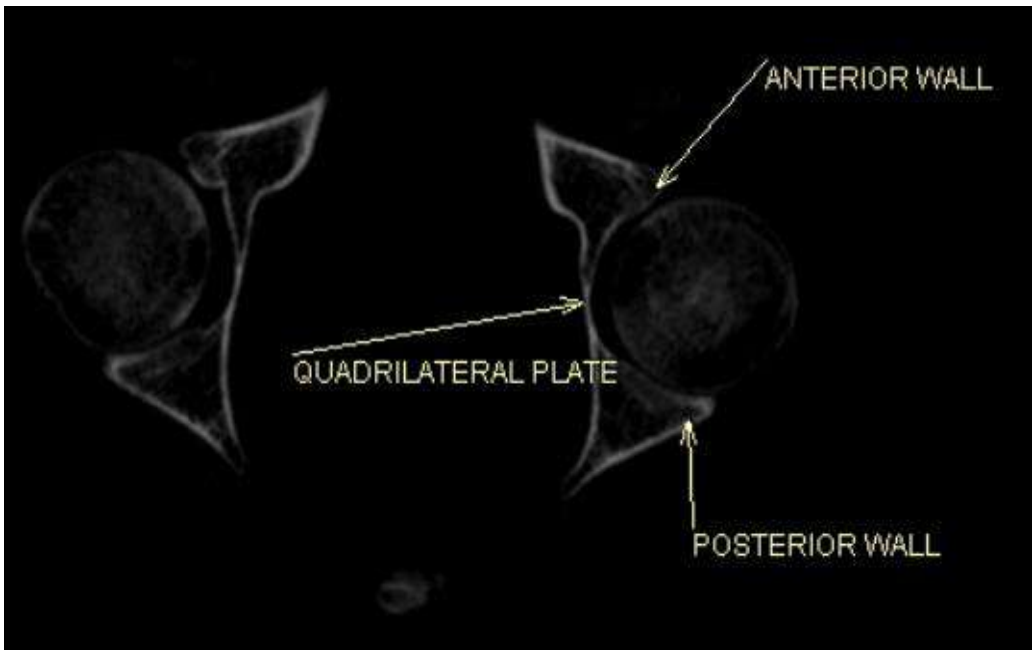
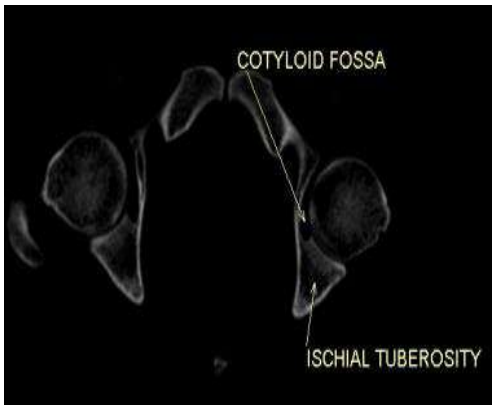

ANTERIOR WALL
QUADRILATERAL PLATE
POSTERIOR WALL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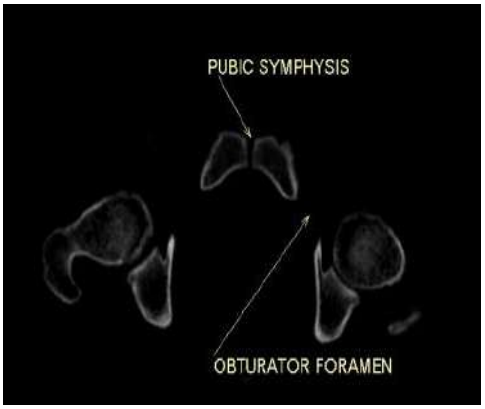
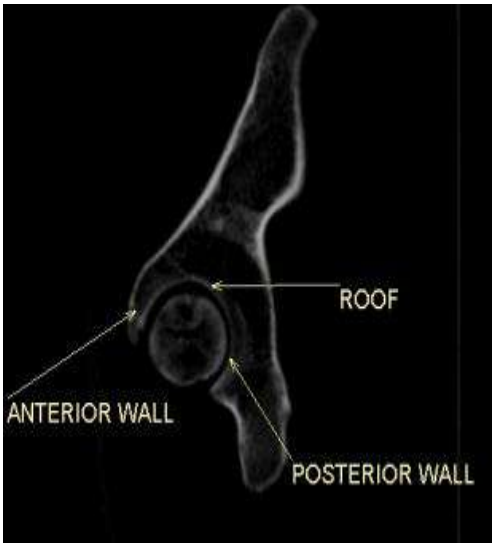
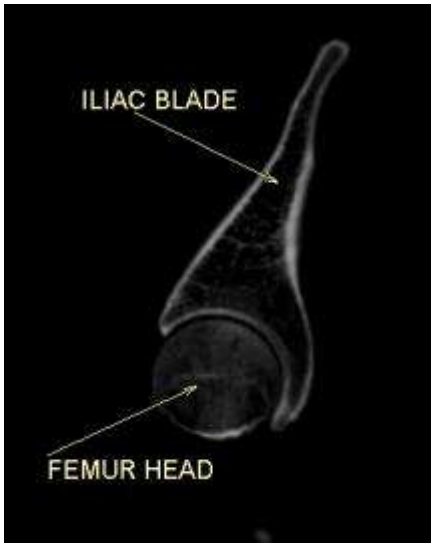
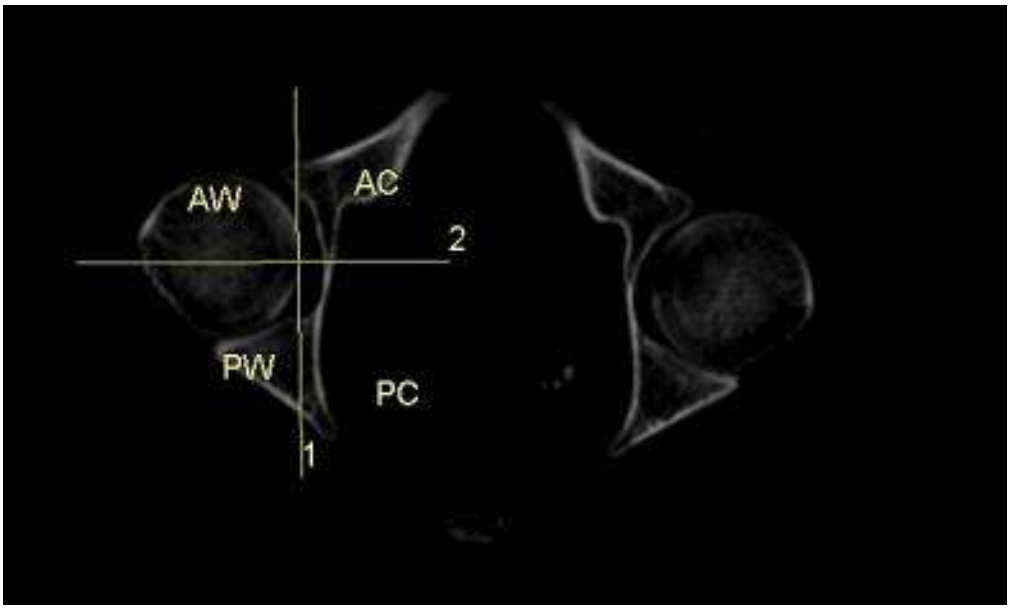
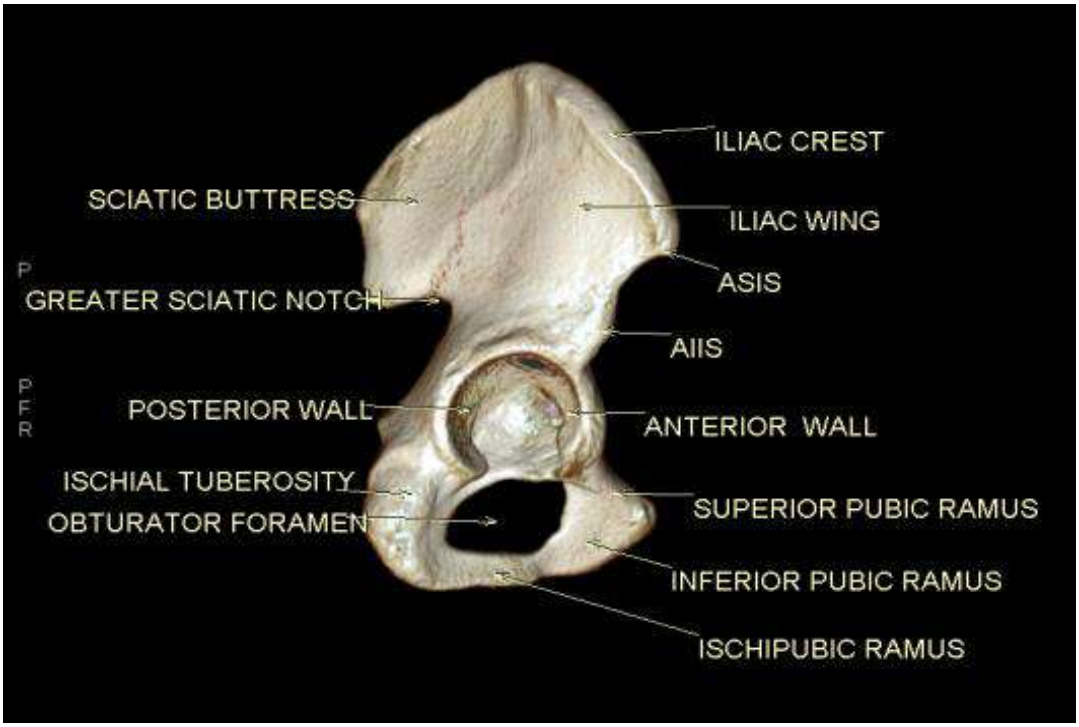

PUBIC SYMPHYSIS
OBTURATOR FORAMEN







Axial section through the acetabulum shows anterior wall (AW), posterior wall (PW), anterior column (AC), and posterior column (PC)


ILIAC CREST
SCIATIC BUTTRESS
ILIAC WING
P
GREATER SCIATIC NOTCH
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POSTERIOR WALL
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SUPERIOR PUBIC RAMUS
OBTURATOR FORAMEN
INFERIOR PUBIC RAMUS
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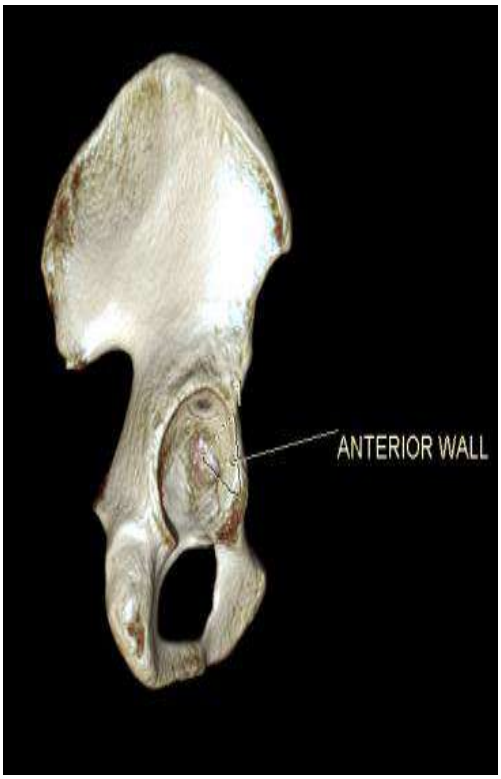
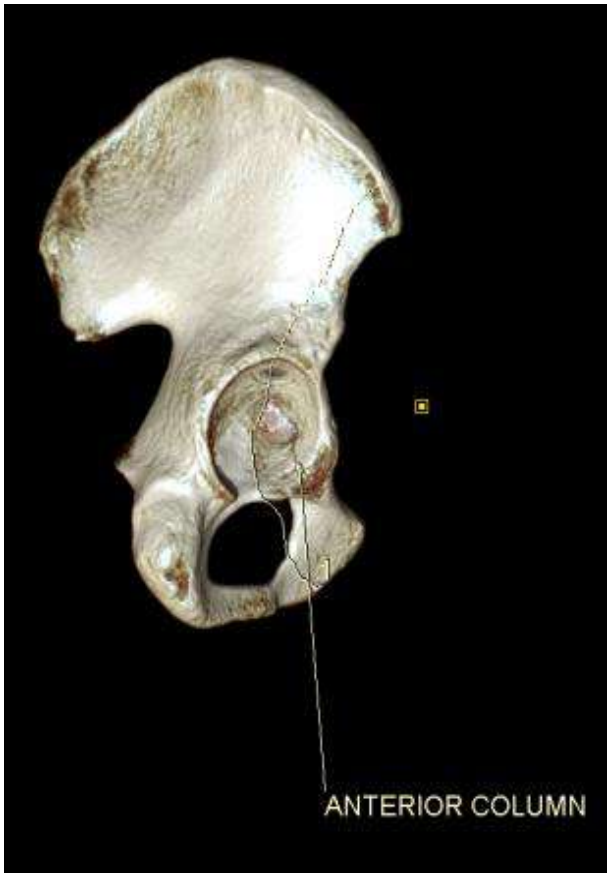
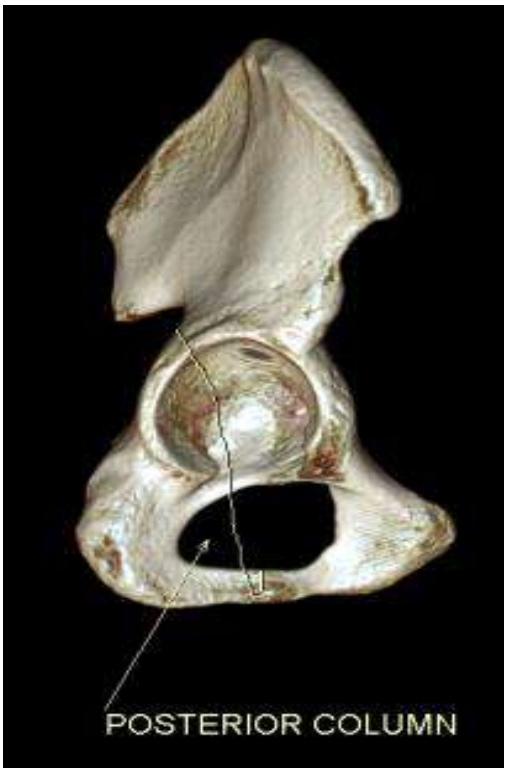

ANTERIOR WALL

POSTERIOR WALL


ANTERIOR COLUMN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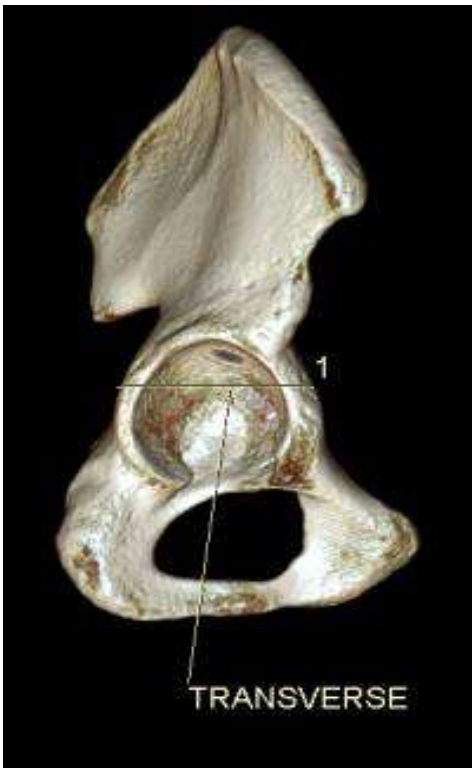
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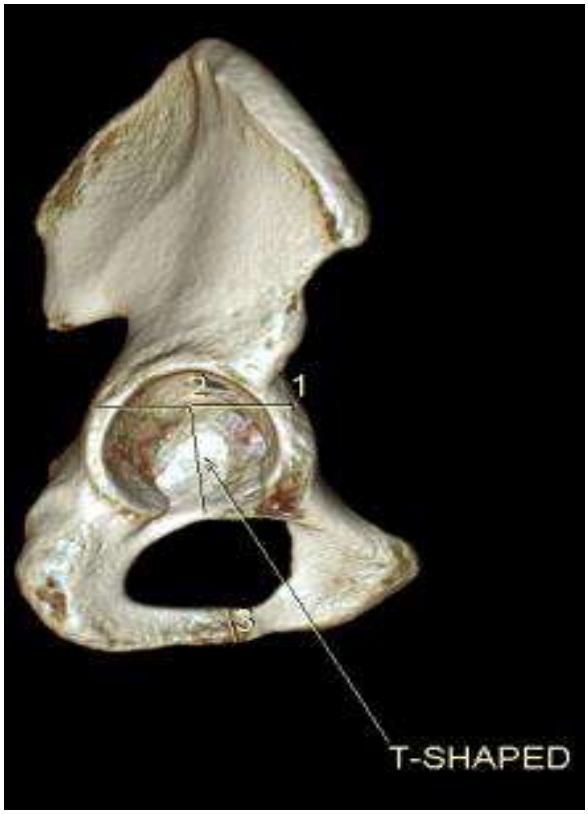
TRANSVERSE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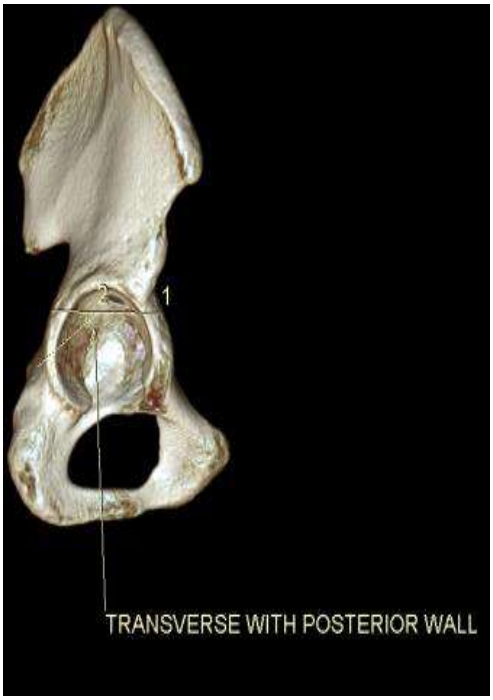
T-SHAPED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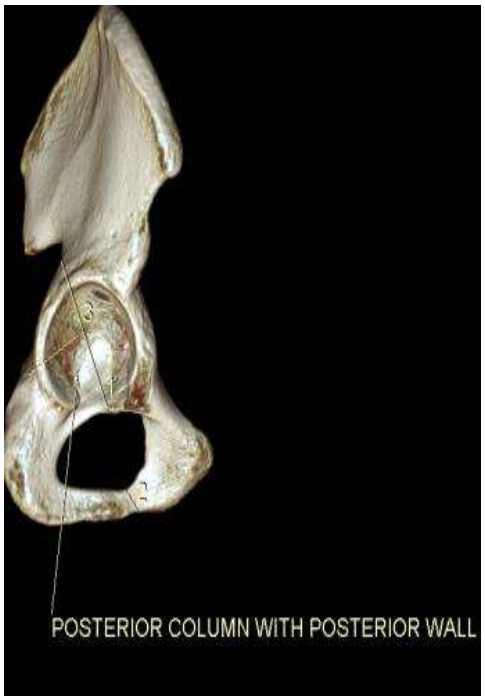
1
TRANSVERSE WITH POSTERIOR WALL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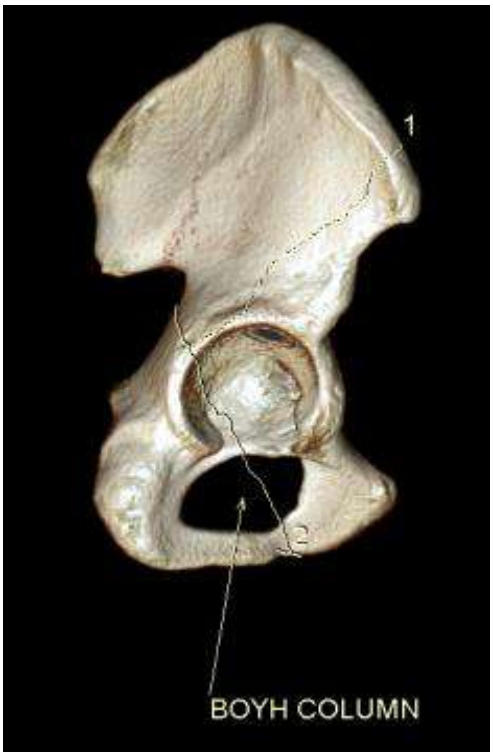
POSTERIOR COLUMN WITH POSTERIOR WALL



Diagrams show the 10 types of fracture in the Judet and Letournel acetabular fracture classification system. Green sacrum = posterior aspect.

ANTERIOR LANDMARKS		LANDMARKS IN NO MANS LAND ZONE			POSTERIOR LANDMARKS		FRACTURES
ILIAC WING	ANTERIOR WALL	ROOF	QP	OR	POST WALL	POST BORDER	
	X	+/-					ANTERIOR WALL
X	X	+/-		X			ANTERIOR COLUMN
		+/-			X		POSTERIOR WALL
		+/-	X	X		X	POSTERIOR COLUMN
	X	+/-				X	TRANSVERSE
	X	+/-			X	X	TRANSVERSE WITH POSTERIOR WALL
X	X	+/-	X	X	X	X	ANTERIOR COLUMN WITH POSTERIOR HEMITRANSVERSE
	X	+/-	X	X	X	X	T-TYPE
X	X	X	X	X	X	X	BOTH COLUMN

AIMS AND OBJECTIVES

1. Evaluation of acetabular fractures by computed tomography.
2. Comparison of multiplanar reformat (MPR) with volumetric rendering techniques (VRT) in fracture detection.

REVIEW OF LITERATURE

Sauser et al[14] (1980) did a study on 13 patients of acetabular fractures, associated dislocation of hip was present in 6 patients, these patients underwent emergency CT examination. CT was found to influence the treatment in 4 patients and provided useful information in several others. CT was found to be helpful especially for evaluating presence or absence of intraarticular osseous loose fragments after reduction of the dislocated hip for evaluating congruity of the joint space after fractures of the femoral head and acetabulum. CT also provided useful information concerning the adjacent soft tissues and associated pelvic fractures.

Shirkhoda et al[15] (1980) evaluated 10 patients of acetabulum fractures with CT followed by AP and 45 degrees oblique radiographs. Each patient was studied with CT in supine position using 10mm slice thickness. Axial sections were obtained from above the acetabulum to below the greater trochanter. Images were evaluated using a wide window setting. In 6 patients, loose bodies within the hip joint were noted in the CT scan but were not noted in the conventional radiographs. In one case, the fracture of the anterior aspect of femoral head was detected on CT but not on the radiographs. Three patients had fractures extending upwards through the iliac and 2 had involvement of the sacroiliac joint, demonstrated well on the CT scan but not on the original radiographs. In addition to these specific anatomical changes, CT showed location and extent of the acetabular fractures much more clearly in all patients.

Oslon et al[16] (1991) stated that CT is an established modality of use in the evaluation of acetabular fractures. As open reduction and internal fixation of acetabular fractures become more common, the need for an accurate understanding of the fracture anatomy is critical.

Martinez et al[17] (1992) gave the classification of acetabular fractures to axial computed tomographic (CT) scans and three-dimensional

reconstructions. In the classification system, fractures are analyzed according to the extent of involvement of two acetabular columns--the posterior and the anterior. They illustrated the most common fractures (posterior wall, transverse, transverse with posterior wall, and both columns) with radiographs, axial CT scans, and three-dimensional reconstructions. Axial CT scans readily demonstrated the fractures and presence of intraarticular fragments. Three-dimensional images helped in understanding the precise plane of the fracture, the degree of disruption of the articular surface, and spatial relationships of fragments. Although present three-dimensional CT is not without limitations, the authors believe that the technique is valuable and that, in their experience, it has facilitated preoperative planning.

The criteria to treat acetabular fractures operatively versus non-operatively by the computerized tomography subchondral arc was given by Olson and Matta[18] (1993). The criteria for selecting cases for non-operative treatment are as follows:

1. The acetabular articular surface is intact in the superior 10 mm of the joint on CT evaluation.
2. When a posterior wall fracture is part of the injury pattern, a minimum of 50% of the posterior wall articular surface is intact at the most involved level as determined by CT

The main advantage of three-dimensional visualization of acetabular fractures was described by **Smet et al**[19] (1995). The authors studied seven adult patients with acetabular fractures were investigated with conventional X-rays, axial spiral computed tomographic (CT) images and three-dimensional (3D) surface rendered reconstructions. According to them advantage of spiral CT is that it acquires the data much faster than incremental CT, resulting in less motion artifacts. The main advantages of three-dimensional visualization of acetabular fractures included: creation of unlimited and unique views by which fracture location, fracture extension, fragment shape and fragment

position became clearer, better visualization of acetabular dome and quadrilateral plate and simpler and easier interpretation of these complex fracture patterns. On the other hand, 3D surface reconstructions do not accurately demonstrate undisplaced fractures, intra-articular fragments may be obscured, congruence assessment is uneasy, and soft tissue injuries are not shown. Therefore, according to them 3D images of acetabular fractures as being complementary to and not a substitute to plain radiographs and axial CT scans.

M. Haveri et al [20] in 1997 conducted a study where he compared multiplanar and 3d ct of acetabular fractures. Acetabular fractures in 15 patients were imaged by means of plain radiographs, transaxial CT, MPR reformats, and SSD reformats. The classification of the acetabular fracture was revised in **7/15** cases when the transaxial CT images were read after the plain radiographs. Although the MPR and SSD reformats did not alter the classification, they did add to the degree of confidence in the diagnosis in 9/15 cases. In 2 patients, the MPR and SSD reformats indicated operative instead of conservative treatment.

In the MPR reformats, the following views were considered essential in all cases:

(a) Along the anterior column;

(b) Along the posterior column; and

(c) Along both columns and the inferior ramus. In the SSD reformats, the following views were considered essential in all cases:

(d) The latero-caudal ***en face*** view into the acetabulum; and 180" opposite to this,

(e) The medio-cranial view (facing the quadrilateral plate).

In **10/15** cases, these views were all that was needed for classification. It was, however, essential to remove the femur from the images before reconstructing the SSD views. The study concluded that complex acetabular fractures with displacement should be evaluated by means of transaxial CT and additional MPR and SSD reformats. The use of

appropriate standard MPR and SSD views shortens the time required to produce the reformats and thereby maximizes the benefit gained.

Another study conducted by **Ralph Kickuth et al** [21] in 2002 on 3D CT versus axial helical CT versus conventional tomography in the classification of acetabular fractures: a ROC analysis. The study was done to assess the diagnostic power of three-dimensional computed tomography (3D CT), axial helical computed tomography (CT) and conventional tomography in the classification of acetabular fractures by interdisciplinary review. The differences between axial helical CT and conventional tomography were not significant. The study concluded that acetabular fractures are best classified by 3D CT, followed by axial helical CT and conventional tomography when assessed by surgeons. 3D CT did not provide any additional significant benefit in the classification performed by radiologists.

Marco Falchi et al[22] (2003) stated that spiral CT provides information regarding the extent of the fractures and is complementary to radiography for ascertaining the spatial arrangement of fracture fragments. Spiral CT is an effective tool for understanding complex fracture patterns, particularly when combined with multi-planar reconstruction two-dimensional (MPR 2D) reformatted images or three-dimensional images (3D) images. Including these techniques of reconstruction in routine pelvic imaging protocols can change management in a significant number of cases. Subtle fractures, particularly those oriented in the axial plane, are better seen on MPR images or 3D volume-rendered images. Complex injuries can be better demonstrated with 3D volume-rendered images, and complicated spatial information about the relative positions of fracture fragments can be easily demonstrated to the orthopaedic surgeons.

Postoperative studies in patients with orthopaedic hardware also benefit from volume-rendered imaging. Volume rendering eliminates most streak artifact and produces high-quality images on which the

relationships among hardware, bones, and bone fragments are well demonstrated.

In a study conducted by **Robert V. O'toole et al**[23] in 2005, they studied if Computed Tomographic (CT) scans improve the ability to classify acetabular fractures in comparison with plain radiographs. Four different image sets for each patient were evaluated: image set A, Judet view plain radiographs plus axial view ct scans; image set B, Judet view plain radiographs alone; Image set C, three-dimensional CT reconstructions; and image set d, ct simulated Anteroposterior and Judet views of the pelvis. The 300 Image sets were viewed in random order by four orthopaedic traumas. Fellowship trained surgeons who independently recorded a diagnosis. A gold standard diagnosis was determined by group consensus. They concluded that in contrast to previous reports in the literature, the accuracy of plain radiographs alone was less than the accuracy of ct scans in terms of diagnosis the interobserver reliability was also worse for plain radiographs alone.

In 2006 **Ohashi et al** [24] conducted a study on interobserver agreement for letournel acetabular fracture classification with multidetector CT: are standard judet radiographs necessary'. Multiplanar reformatted and three-dimensional (3D) CT images were reviewed at a computer workstation. The reference standard was a combination of preoperative radiographic and multidetector CT image findings and intraoperative findings. The study concluded that here is substantial interobserver agreement for Letournel acetabular fracture classification with multiplanar reformatted and 3D multidetector CT images. Standard Judet pelvic radiographs add little information for changing the multidetector CT classification.

In a study conducted in 2007 by **Mats Geijer et al** [25], on Imaging of the acetabulum in the era of multidetector computed tomography which illustrated that Understanding and classification of these rare injuries using radiography can be difficult and are much facilitated by the

addition of computed tomography (CT). MDCT with MPR and 3-D reconstructions is an indispensable imaging tool in the detection and work-up of acetabular fractures before and after treatment. The CT examination should be performed with thin axial slices to allow for near-isotropic imaging. The thin slices are also necessary to properly evaluate the articular surfaces and search for entrapped intra-articular osteochondral fragments. A slice thickness of 2 mm or less reconstructed at 1 mm or smaller interval gives good results. In polytrauma patients, where a chest, abdomen, and pelvis CT has already been performed, dedicated acetabular MDCT imaging is usually not necessary because the raw data for acetabular imaging have already been acquired and are stored on the CT scanner. It may be necessary, using the raw data, to reconstruct axial slices thin enough to allow for good MPR and 3D reconstructions, which should then be sent to a dedicated workstation, where secondary reconstruction is performed.

Another study was done by **O'TOOLE et al** [26] in 2010 on evaluation of computed tomography for determining the diagnosis of acetabular fractures. It included Seventy-five patients with 75 acetabular fractures. Four different image sets for each patient were evaluated: image set A, Judet view plain radiographs plus axial view CT scans; image set B, Judet view plain radiographs alone; image set C, three-dimensional CT reconstructions; and image set D, CT simulated anteroposterior and Judet views of the pelvis. A gold standard diagnosis was determined by group consensus. The study concluded that the accuracy of plain radiographs alone was less than the accuracy of CT scans in terms of diagnosis. The interobserver reliability was also worse for plain radiographs alone.

P. Jouffroy et al [27] conducted a study in 2016 on improved acetabular fracture diagnosis after training in a CT-based method. 35 cases of acetabular fractures that replicated the overall distribution of fracture types were selected. The images were reviewed. The rates of correct

diagnoses and times needed to read the images were compared. Finally, an additional reading was performed to allow an assessment of reproducibility. So it was concluded that by analysing the eight anatomical landmarks located in the anterior, posterior, and no man's land zones is a simple and reproducible method for diagnosing all fracture patterns defined by the Letournel classification.

Another study conducted by Guillaume **Riouallon et al** [28] in 2016 in which he designed a new, easy, fast, and reliable method to correctly classify acetabular fractures according to the letournel system. To aid in the classification of acetabular fractures and to aid in teaching, their department developed a diagnostic algorithm that involves the use of 1 standardized 3-dimensional reconstruction of a computed tomography (CT) scans with 8 anatomical landmarks. Acetabular fractures were evaluated in 2 phases. The primary outcome was the accuracy of classification. The study concluded that the Letournel classification system is difficult to understand and to learn but remains the only system guiding the surgical strategy for acetabular fractures. The impact of diagnostic algorithms is debatable. The most important finding of the present study is the high accuracy for inexperienced groups when the app was used. Another important finding is the high reliability of this method for the diagnosis of complex acetabular fractures.

One of the studies conducted in 2017 by **Amer Sebaaly et al** [29] on Standardized three dimensional computerized tomography scanner reconstructions increase the accuracy of acetabular fracture classification. The purpose of the study was to evaluate the role of four standardized 3D reconstruction views in the accurate diagnosis of acetabular fractures. Sets of images which were provided in axial 2D views and multiplanar reconstruction (MPR) without 3D views in the first two readings then the standardized 3D views were added for the subsequent two readings. It concluded that acetabular fracture diagnosis according to Letournel classification is difficult and depends

greatly on the experience of the reader. The described set of 3D images yields better accuracy and renders the diagnosis more repeatable and faster. We recommend the use of these images in classifying acetabular fractures.

Holger Keil et al [30] (2018) conducted a study on intraoperative assessment of reduction and implant placement in acetabular fractures—limitations of 3D-imaging compared to computed tomography. Twenty consecutive cases of acetabular fractures were selected with a complete set of intraoperative 3D imaging and postoperative CT data. The largest detectable step and the largest detectable gap were measured in all three standard planes. These values were compared between the 3D data sets and CT data sets. The study concluded that intraoperative 3D imaging is a valuable adjunct in assessing reduction and implant placement in acetabular fractures but has limitations due to artifacts caused by implant material. This can lead to missed malreduction and impairment of clinical outcome, so postoperative CT should be considered in these cases.

Zhenfei Huang et al [31] (2018) stated that conventional education results have unsatisfactory morphological understanding of acetabular fractures due to lack of three-dimensional (3D) details and tactile feedback of real fractures. Virtual reality (VR) and 3D printing (3DP) techniques are widely applied in teaching. The purpose of the study was to identify the effect of physical model (PM), VR and 3DP models in education of morphological understanding of acetabular fractures. Three-level objective tests were conducted to evaluate learning, including identifying anatomical landmarks, describing fracture lines, identifying classification, and inferring fracture mechanism. Generally, the 3DP group showed a clear advantage over the PM and VR groups in objective tests, while there was no significant difference between the PM and VR groups. 3DP was considered to be the most valuable learning tool for understanding acetabular fractures. The findings demonstrate that 3DP modelling of real fractures is an effective

learning instrument that can be used to understand the morphology of acetabular fractures and promote subjective interest.

Introduction of a three-dimensional computed tomography measurement method for acetabular fractures was done by **A.M.L Meesters et al** [32] **(2019)** which stated that 2DCT measurements tend to underestimate the initial and residual displacement in complex acetabular fractures. A 3DCT analysis of these injuries was developed to overcome this and should be used in addition to the Judet/Letournel and AO/OTA classification systems, in order to provide an observer independent quantifiable fracture description and accurate assessment of the fracture reduction.

A study conducted in 2019 by **Thanat Kanthawang** et al [33] comparing the accuracy and timeliness of two-dimensional computed tomography (2DCT) and three dimensional computed tomography (3DCT) in the diagnosis of different types of acetabular fractures and by different groups of interpreters uses the Letournel and Judet classification system. Twenty-five fractures cases, five each of five common types of acetabular fractures, were selected. Improvement occurred in the interpretation of transverse and posterior wall-type fractures, but not in T type, transverse with posterior wall, or both-column fractures. The study concluded that Standardized 3DCT provides greater reliability and faster diagnosis of acetabular fractures and helps improve the accuracy in transverse- and posterior wall-type fractures. In addition, it helps improve the accuracy of less experienced interpreters.

MATERIALS AND METHODS

Source of Data

The study included both outdoor and indoor patients with acute pelvic trauma being referred to the department of Radiodiagnosis, Dayanand medical college and hospital for Multidetector Computed Tomography.

Method Of Collection Of Data

The study was conducted over a period of one year.

50 patients suspected to have pelvic fractures were included in study. Consent was obtained from each patient and relevant detailed history was elicited from all patients.

Technique of imaging

Low dose unenhanced MDCT in all patients included in this study was carried out on Somaton definition and 128 slice CT machine by Siemens Germany Std with a gantry rotation speed of 0.5 second ,tube current of 100-350 mA, reconstruction increment of 1.0 mm and slice thickness of 1 mm in the Department of Radiodiagnosis and Imaging, Dayanand Medical College and Hospital, Ludhiana.

Positioning of the patient

Patient was positioned supine, head first and arms above the head. Pillows were used to help patient maintain the correct position and to hold still during the examination. During the entire period of the procedure patient was in contact with technologist/doctor by two way intercom system.

CT Protocol

All scans were acquired in cephalocaudal direction. First topogram was taken and then scanning was done at l20kvp and mAs of 60.

INCLUSION CRITERIA

- The subject population included patients of any age of both sexes suspected clinically or on the basis of other investigations, including plain radiography, to have acute acetabular fracture(s).

EXCLUSION CRITERIA

- Pathological fractures
- Patients who do not give consent for the study

STUDY DESIGN

This is a longitudinal, prospective study.

OBSERVATIONS AND RESULTS

The present prospective study comprised of 50 patients with clinically suspected or known hip fractures admitted in emergency or orthopedics wards of Dayanand Medical College and Hospital. These patients were referred to the Department of Radio-Diagnosis, for the computed tomographic evaluation of hip.

This study compared the accuracy and timeliness of multiplanar (two-dimensional) computed tomography and volume rendering (three-dimensional) computed tomography in the diagnosis of acetabular fractures. All the cases were first interpreted by the resident radiologist (myself) in multiple sessions and each of the fracture was categorized according to the Judet and Letournel Classification.

All the cases and the volume rendered images were reviewed by the senior consultant radiologist (supervisor) and the final consensus was reached for each case.

TABLE 1

AGE DISTRIBUTION

Age (years)	No. of cases	Percentage
0-20	2	4.0%
20-40	21	42.0%
40-60	20	40.0%
> 60	7	14.0%
Total	50	100.0%

The patients from nearly all the age groups were involved, the maximum number (42%) of the patients were in the age group of 20-40 yrs. Only two patients included in the study were below 20 years and only seven patients were above 60 years of age.

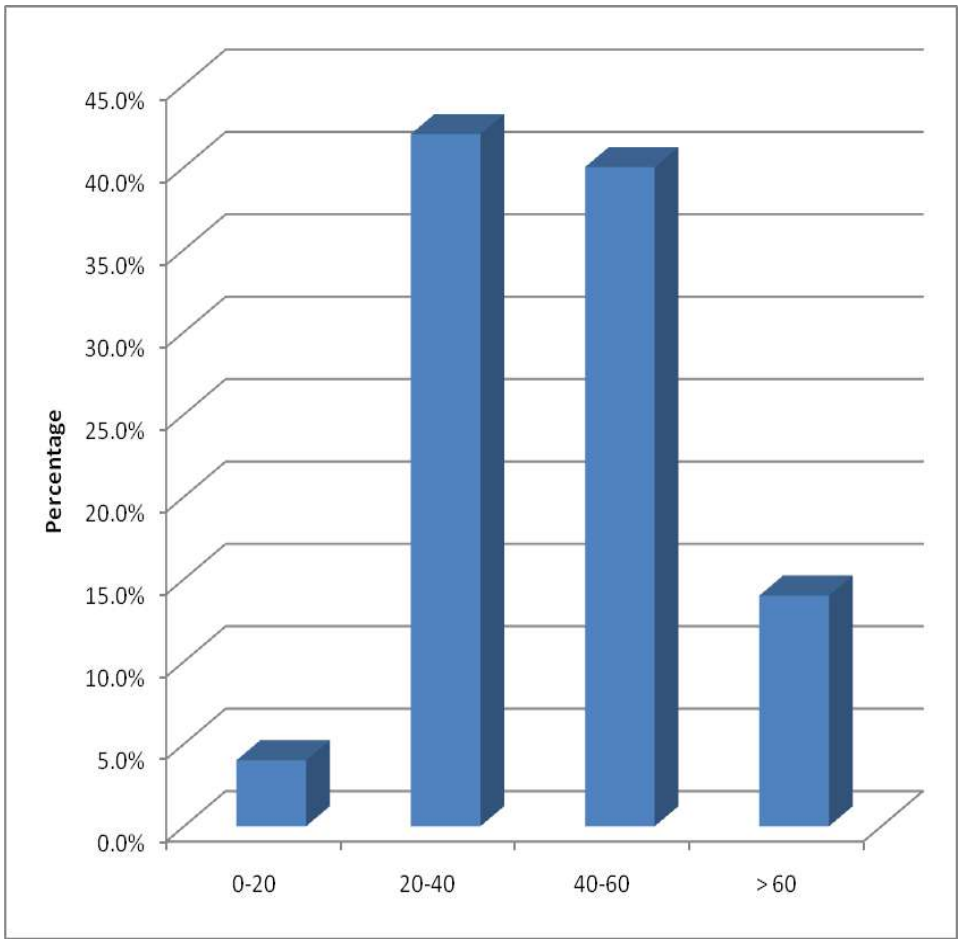


FIGURE 1: AGE DISTRIBUTION

TABLE 2

SEX DISTRIBUTION

Sex	No. of cases	Percentage
Male	32	64.0%
Female	18	36.0%
Total	50	100.0%

Males were seen to be frequently involved in the pelvic trauma as compared to female. Males were 64% as compared to females which were 36%.

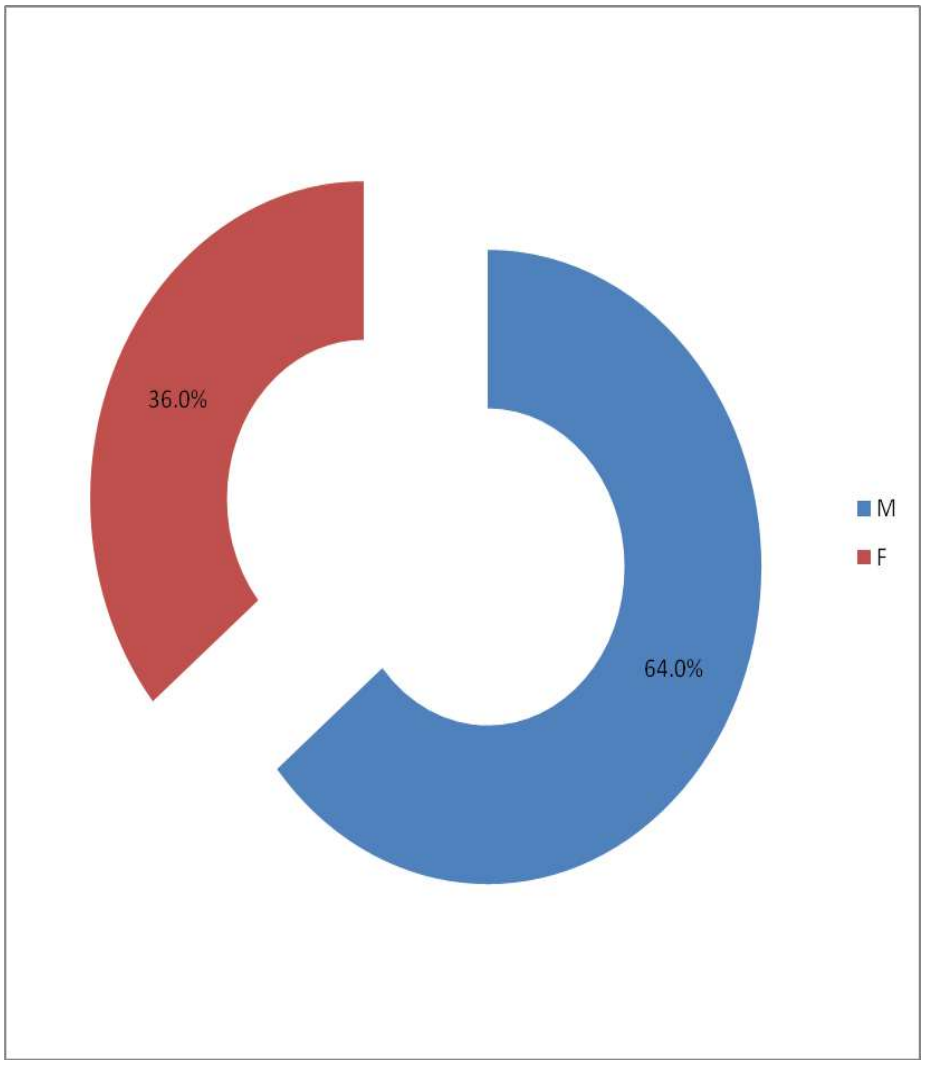


FIGURE2: SEX DISTRIBUTION

TABLE 3

MODE OF INJURY

Cause of injury	No. of cases	Percentage
Fall	13	26.0%
RSA	37	74.0%
Total	50	100.0%

Roadside accidents were the most common etiologic factor resulting in acetabular fractures contributing to 37 patients (74%) in our study followed by only 13 patients (26%) who had a history of fall from height leading to pelvic injury.

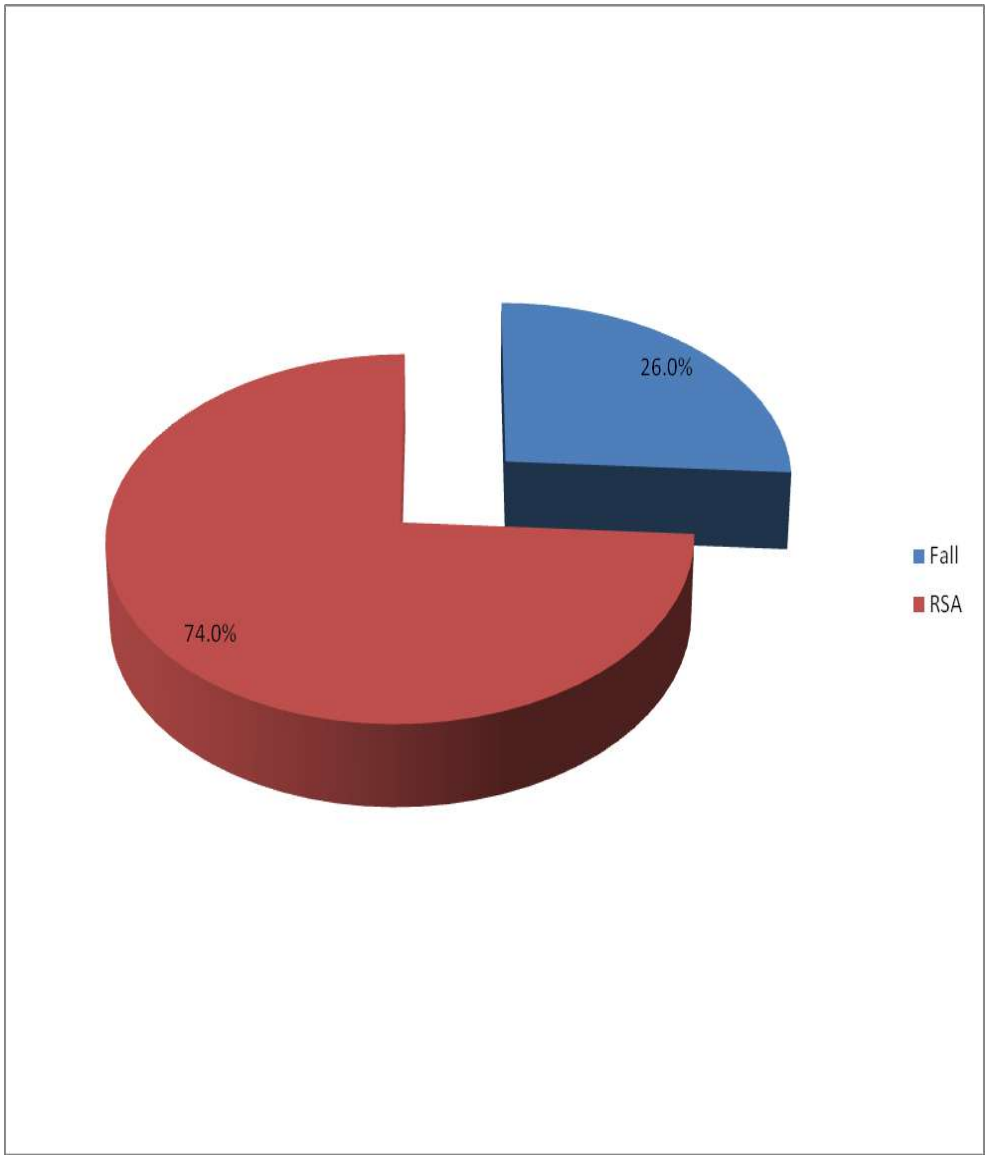


FIGURE3: MODE OF INJURY

TABLE 4

UNILATERAL OR BILATERAL ACETABULAR FRACTURES SEEN ON COMPUTED TOMOGRAPHY (N=50)

	No. of cases	Percentage
Unilateral	46	92.0%
Bilateral	4	8.0%
Total	50	100.0%

Unilateral acetabular fractures were seen in 46 patients and bilateral acetabular fractures were seen in 4 patients on CT.

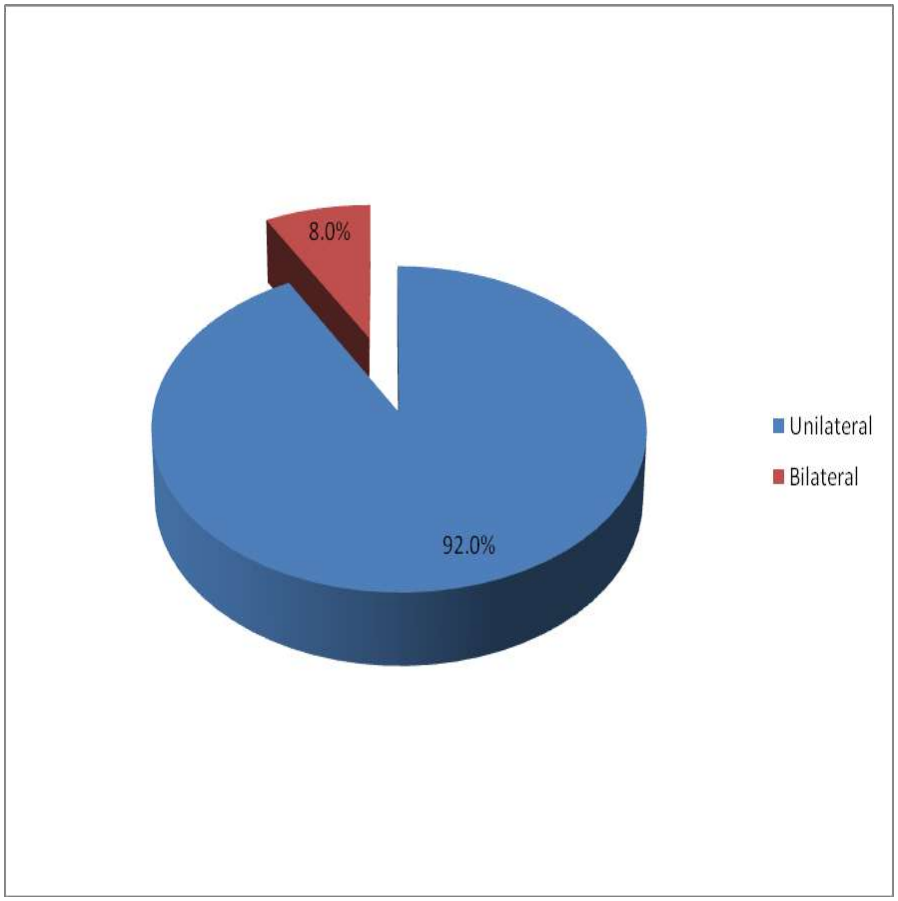


FIGURE 4: UNILATERAL OR BILATERAL ACETABULAR FRACTURES ON COMPUTED TOMOGRAPHY

TABLE 5

PATTERN OF ACETABULAR FRACTURES AS DETECTED ON COMPUTED TOMOGRAPHY (N=50)

Type	No. of cases	Percentage
Comminuted	36	72.0%
Linear	14	28.0%
Total	50	100.0%

Acetabular fractures were seen in 50 patients on CT, out of these patients, pattern of comminuted fracture was seen in 36 patients and 14 patients had linear pattern on CT.

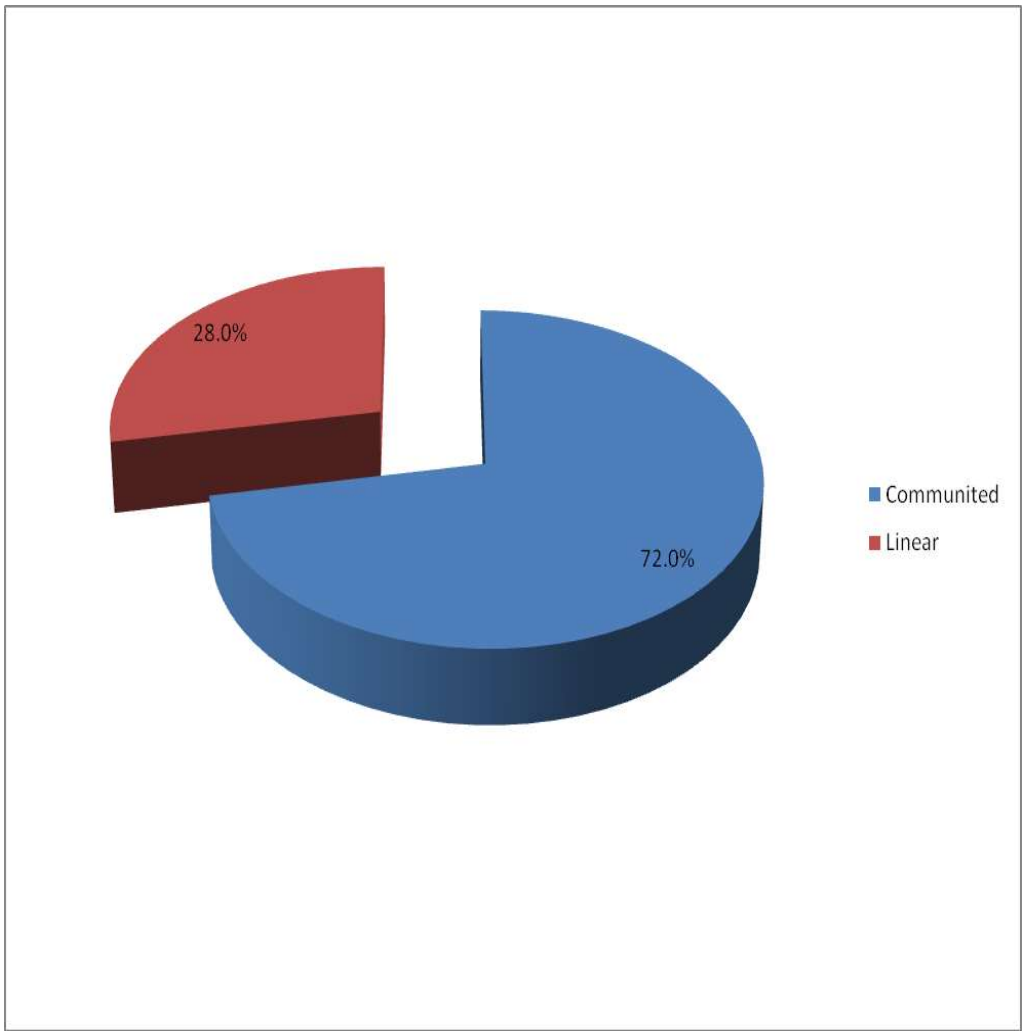


FIGURE 5: PATTERN OF ACETABULUM FRACTURES AS DETECTED ON COMPUTED TOMOGRAPHY (N=50)

TABLE 6

DISLOCATION OF FEMORAL HEAD AS DETECTED ON COMPUTED TOMOGRAPHY

Dislocation of femoral head	No. of cases	Percentage
Positive	14	28
Negative	36	72
Total	50	100.0%

Out of 50 positive cases of acetabular fractures, associated dislocation of the femoral head was seen in only14 cases. Most of the patients with dislocation underwent reduction of the dislocated hip.

TABLE 7

TYPE OF DISLOCATION OF FEMORAL HEAD DETECTED ON COMPUTED TOMOGRAPHY

Type	No. of cases	Percentage
Anterior	5	10
Posterior	9	18

Acetabular fractures were associated with dislocation of the femoral head in 14 cases. Out of these, posterior dislocation was seen in 9 cases, central dislocation in none of these cases where as anterior dislocation in 5 cases.

TABLE 8

DISTRIBUTION OF ACETABULUM FRACTURES ON COMPUTED TOMOGRAPHY (N=50)

Fracture	No. of cases	Percentage
Anterior wall	35	70.0%
Posterior wall	15	30.0%
Anterior Column	25	50.0%
Posterior Column	19	38.0%
Roof	27	54.0%
QP	17	34.0%

Most commonly involved segment of the acetabulum was the anterior wall and roof seen in 70% and 54% of the cases respectively. Involvement of anterior and posterior columns was seen in 50% and 38%. The posterior wall was the least involved segment seen in 30% of the cases**.**

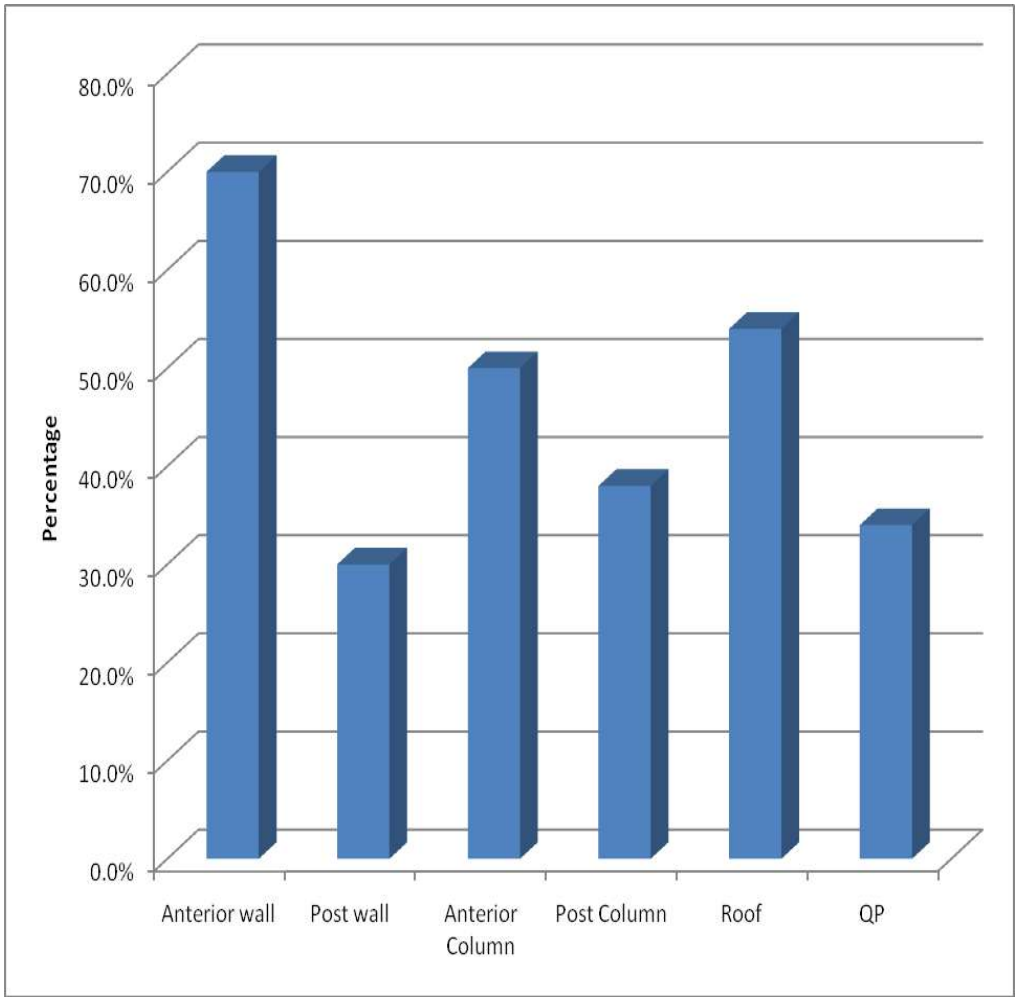


FIGURE 8: DISTRIBUTION OF ACETABULUM FRACTURES ON COMPUTED TOMOGRAPHY (N=50)

TABLE 9

ASSOCIATED FRACTURES OF PELVIC BONES ON COMPUTED TOMOGRAPHY (N=50)

Part involved	No. of cases	Percentage
Iliac bone	19	38.0%
Sacrum	18	36.0%
Rami	34	68.0%
Femur Head	3	6.0%

Along with acetabular fractures, the fractures of the pelvic bones were detected. Fractures involving the pubic rami were seen in 34 cases (68%), fracture involving the iliac bone was seen in 19 cases (38%), and fracture of the sacrum was seen in 18 cases (36%). The least associated fracture was that of femur head which was seen only in 3 cases (6%)

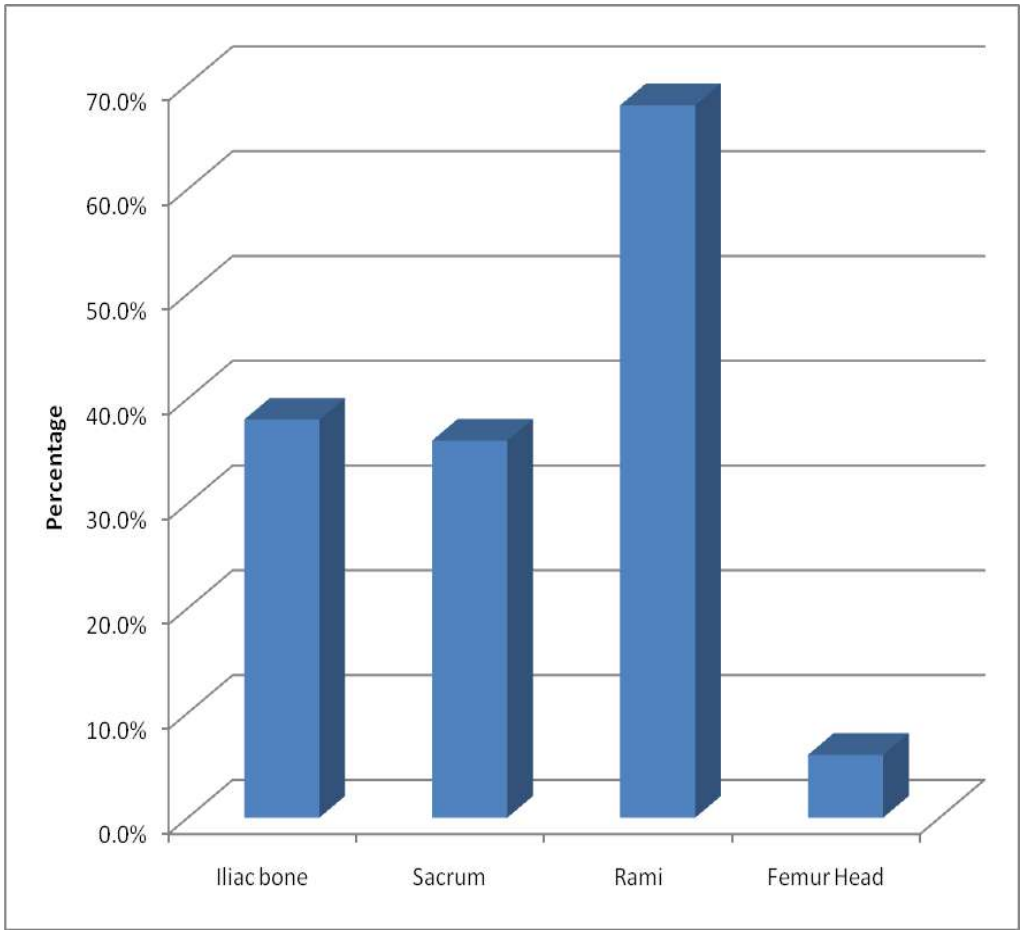


FIGURE 9: ASSOCIATED FRACTURES OF PELVIC BONES ON COMPUTED TOMOGRAPHY (N=50)

TABLE 10

ISOLATED ACETABULAR/ ACETABULAR + PELVIC BONE FRACTURES AS SEEN ON COMPUTED TOMOGRAPHY

	No. of cases	Percentage
Isolated acetabular fracture	7	14.0%
Acetabular + Pelvic bone	43	86.0%

Isolated fracture of the acetabulum was seen in only 7 cases (14%). However, acetabular fractures with a component of the pelvic bone were seen in 43 cases (86%).

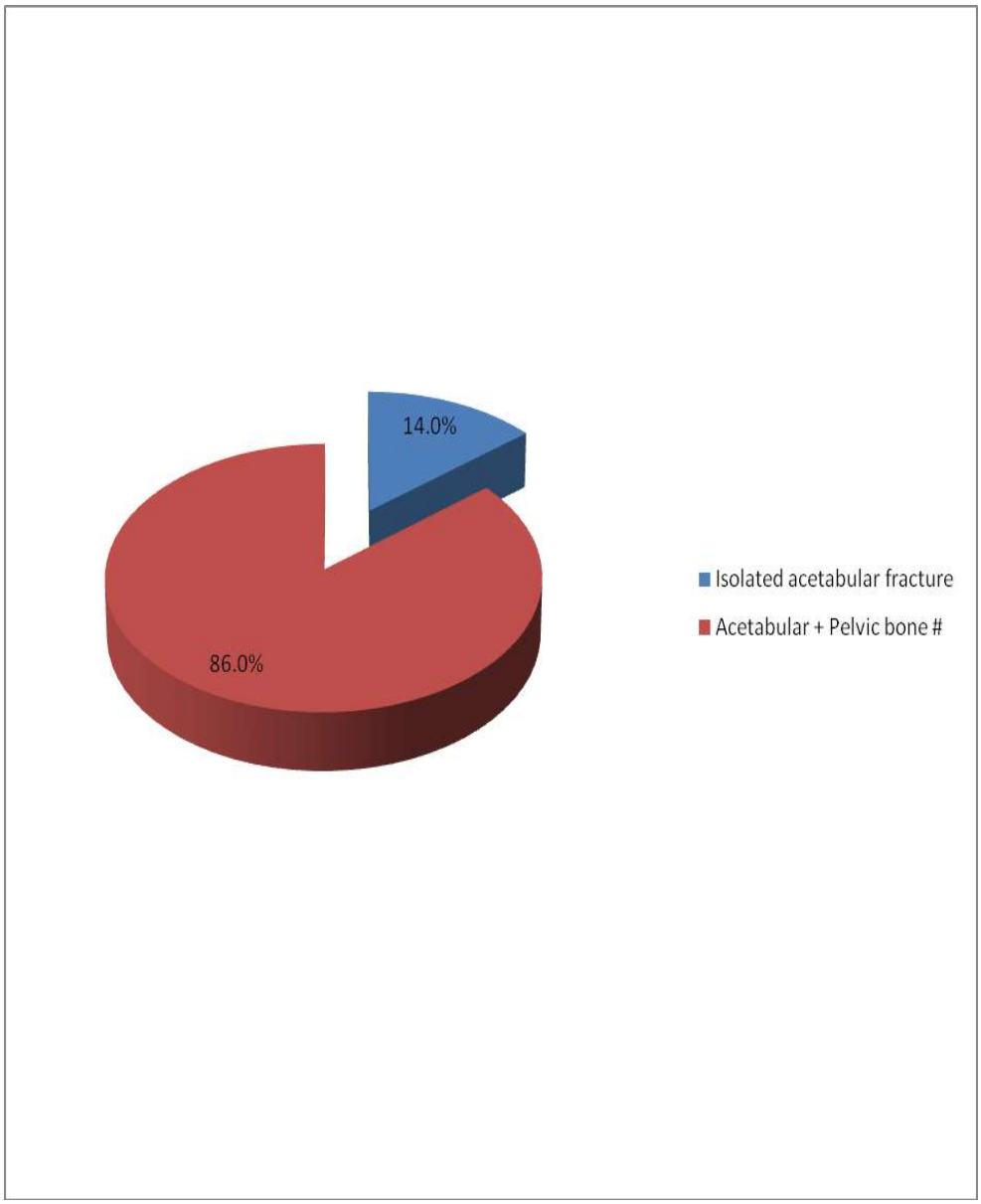


FIGURE 10: ISOLATED ACETABULAR/ACETABULAR + PELVIC BONE FRACTURES AS SEEN ON COMPUTED TOMOGRAPHY

TABLE 11

SINGLE SEGMENT OR MULTIPLE SEGMENT FRACTURES OF ACETABULUM AS DETECTED ON COMPUTED TOMOGRAPHY (N=50)

SEGMENT	No. of cases	Percentage
Single segment	20	40.0%
Multiple Segment	30	60.0%

Acetabular fractures were studied in 50 patients on CT. In 30 patients (60%) there were fractures of multiple segments of acetabulum whereas single segment was fractured in 20 patients (40%)

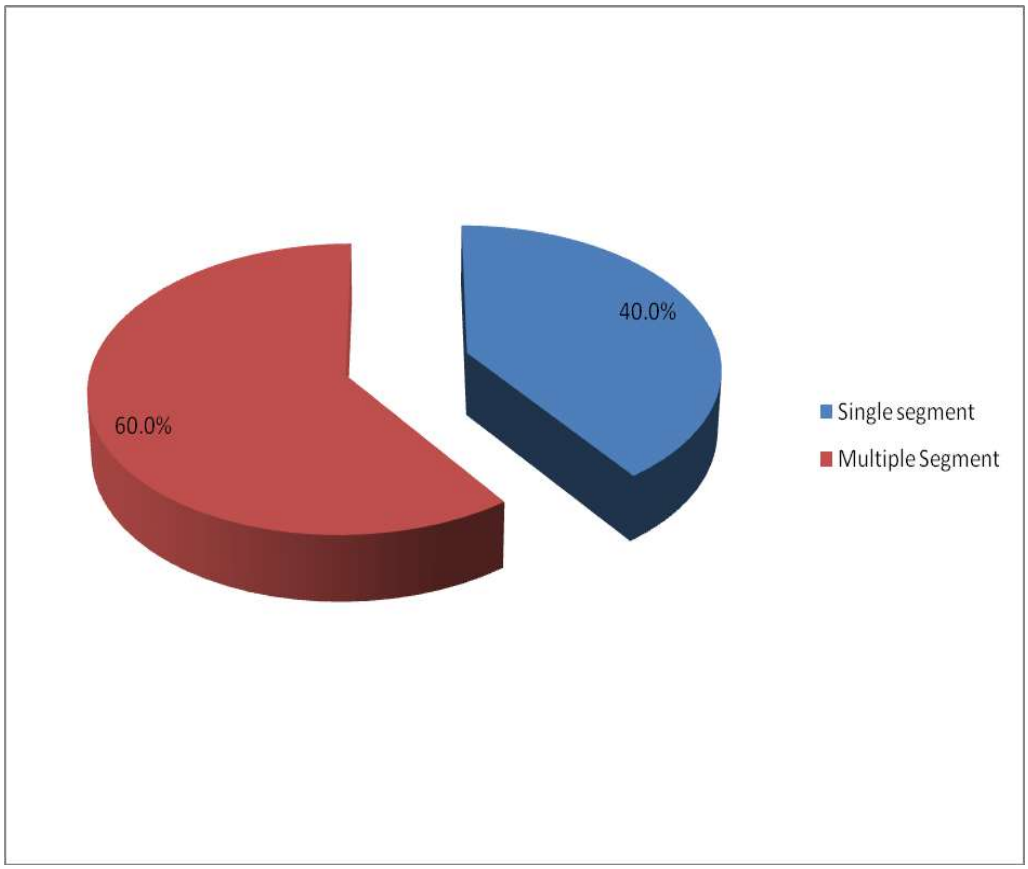


FIGURE 11: SINGLE SEGMENT OR MULTIPLE SEGMENT FRACTURES OF ACETABULUM AS DETECTED ON COMPUTED TOMOGRAPHY (N=50)

TABLE 12

COMBINATION OF PELVIC FRACTURES AS DETECTED ON CT

Combination	No. of cases	Percentage
Fracture of both columns	15	30.0%
Fracture roof & QP of acetabulum	32	64.0%
Fracture Anterior & posterior walls of acetabulum	22	44.0%

In some patients, more than one segment of acetabulum was fractured. The most common combination was seen in the roof and quadrilateral plate of the acetabulum which were seen in 32 cases (64%)

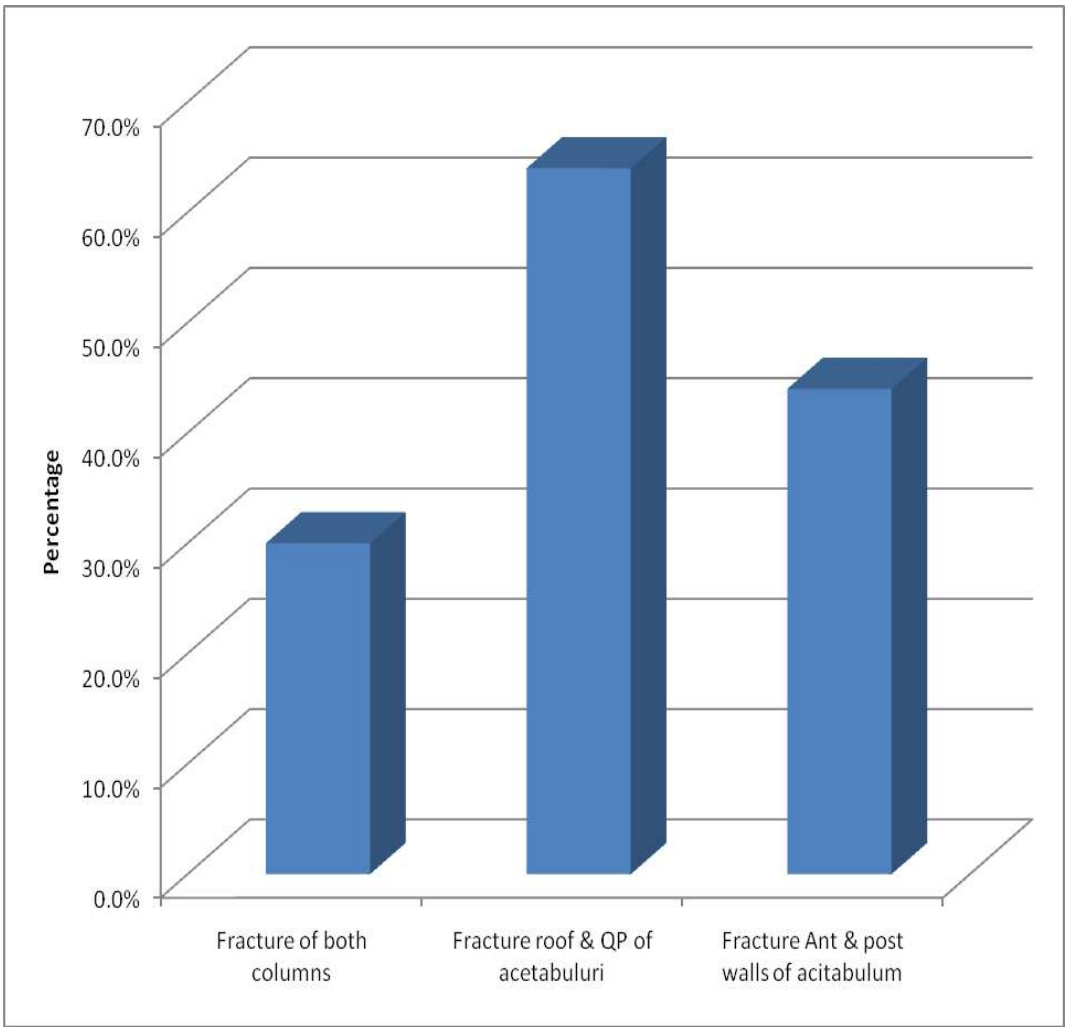


FIGURE 12: COMBINATION OF PELVIC FRACTURES AS DETECTED ON CT

TABLE 13

INTRA-ARTICULAR FRACTURE FRAGMENTS DETECTED ON COMPUTED TOMOGRAPHY

Intra articular Bony Fragments	No. of cases	Percentage
Present	21	42.0%
Absent	29	58.0%

Intra articular bony fragments were detected in 42% of patients on CT. These fracture fragments are difficult to detect on the volume rendering technique imaging.

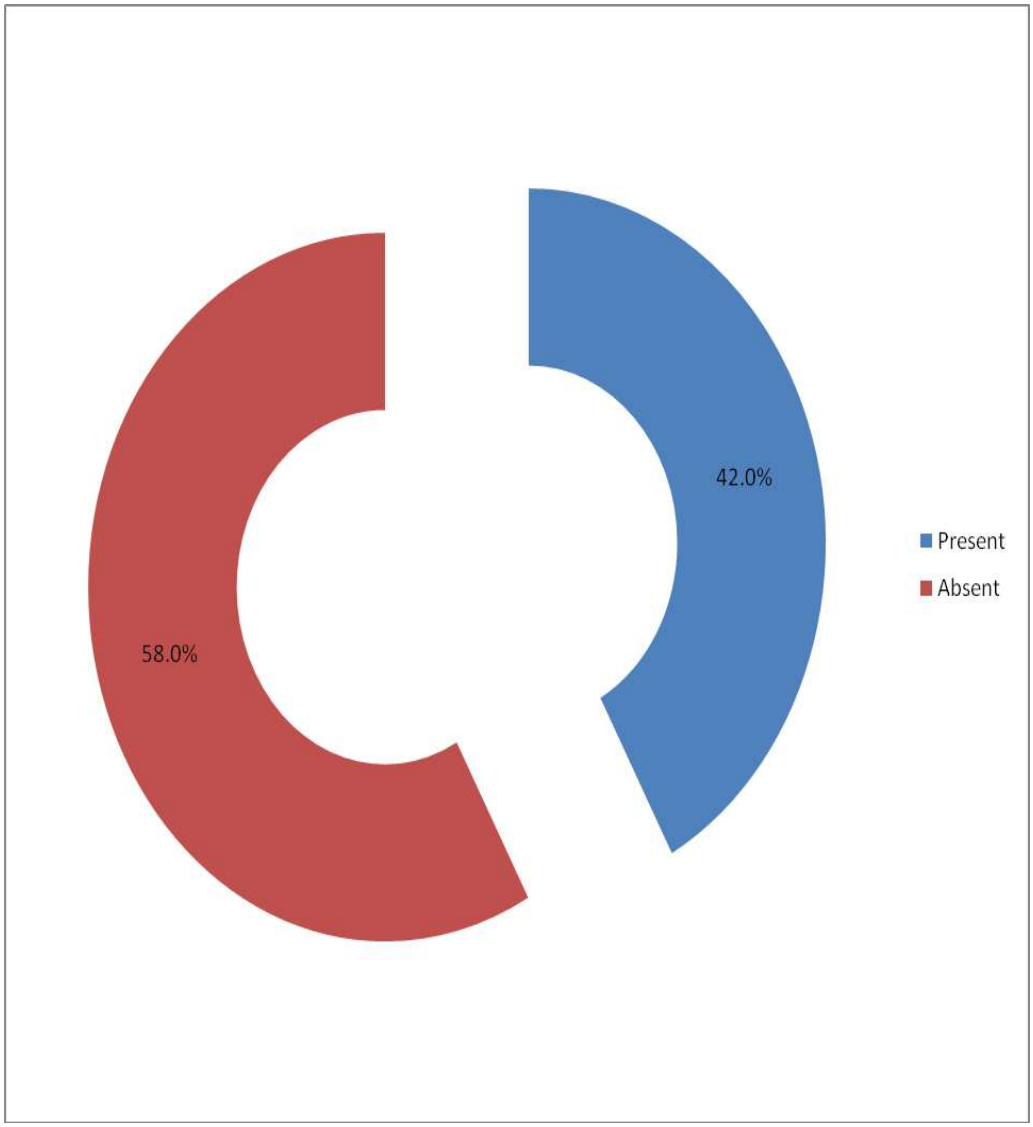


FIGURE 13: INTRA-ARTICULAR FRACTURE FRAGMENTS DETECTED ON COMPUTED TOMOGRAPHY

TABLE 14

DISPLACEMENT OF FRACTURE FRAGMENTS AS DETECTED ON COMPUTED TOMOGRAPHY

Displacement of fractured fragments	No. of cases	Percentage
Present	39	78.0%
Absent	11	22.0%

The displacement of fracture fragments are seen both multiplanar reformat imaging and on volume rendering techniques. The displaced fracture fragments were seen in 39 cases (78%) and undisplaced fragments were seen in 11 cases (22%).

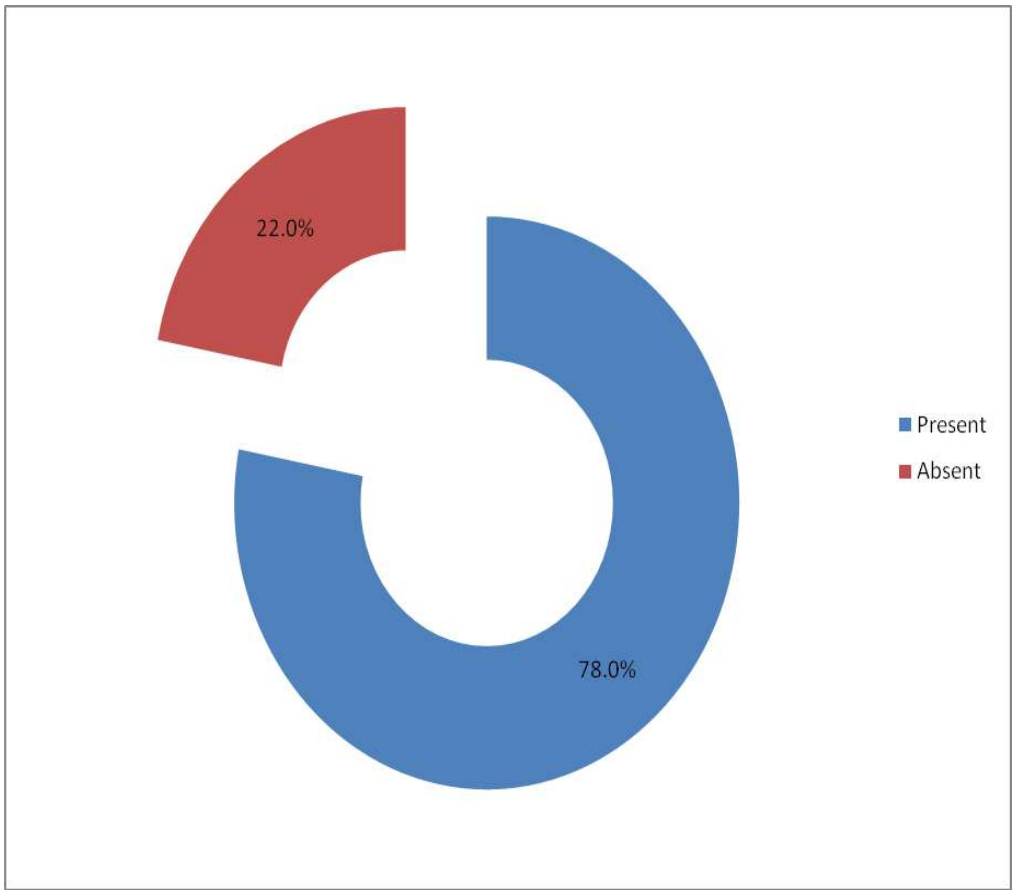


FIGURE 14: DISPLACEMENT OF FRACTURE FRAGMENTS AS DETECTED ON COMPUTED TOMOGRAPHY

TABLE 15

EXTENSION OF FRACTURE LINE FROM THE ACETABULUM AS SEEN ON COMPUTED TOMOGRAPHY

Extension of fracture line	No. of cases	Percentage
Present	32	64.0%
Absent	18	36.0%

The extension of fracture lines from acetabulum in the adjacent pelvic structures were seen on 32 cases (64%) and were absent in 18 cases (36%) on computed tomography.

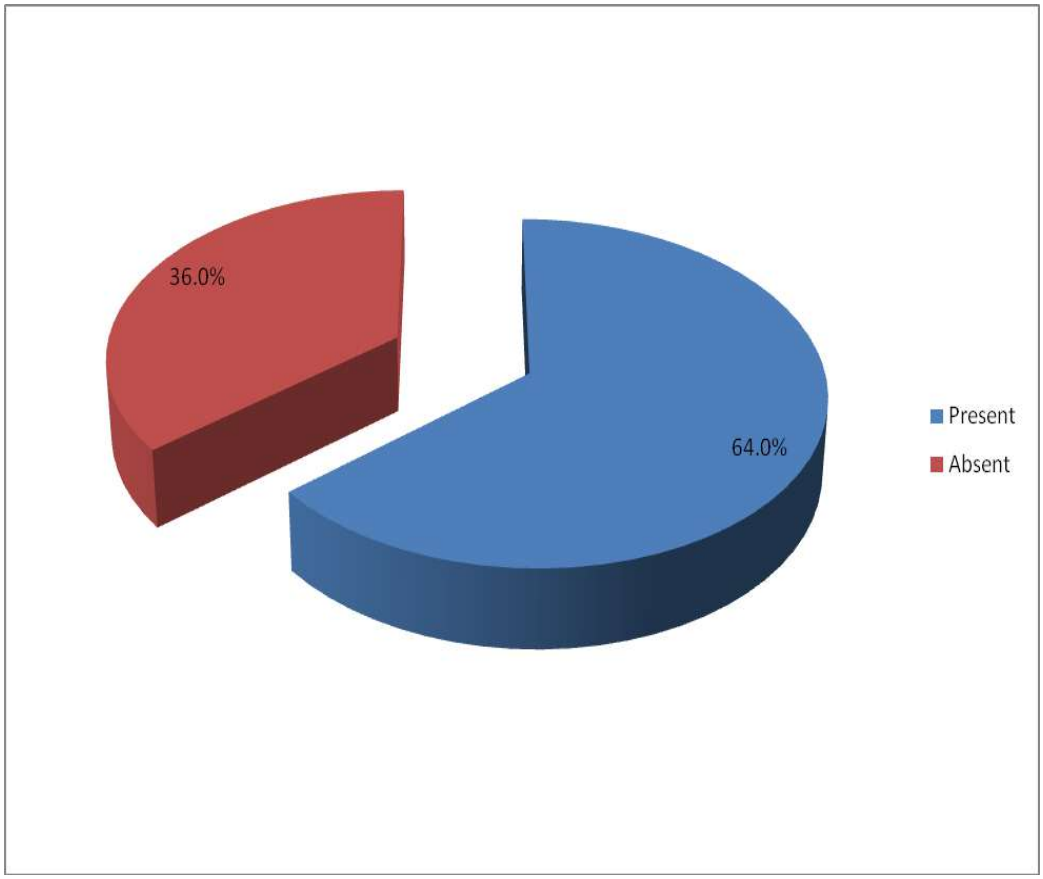


FIGURE 15: EXTENSION OF FRACTURE LINE FROM THE ACETABULUM AS SEEN ON COMPUTED TOMOGRAPHY

TABLE 16

NUMBER and PERCENTAGE OF EACH FRACTURE TYPE

FRACTURE TYPE	N0. OF FRACTURES	PERCENTAGE
ANTERIOR WALL	DISPLACED- 8	16
	UN DISPLACED- 7	14
ANTERIOR COLUMN	7	14
POSTERIOR WALL	DISPLACED- 4	8
	UNDISPLACED- 2	4
POSTERIOR COLUMN	2	4
TRANSVERSE	2	4
T-TYPE	4	8
TRANSVERSE WITH POSTERIOR WALL	8	16
BOTH COLUMN	5	10
ANTERIOR COLUMN WITH POSTERIOR HEMITRANSVERSE	1	2
TOTAL	50	100

TABLE 17

COMPARISON OF FRACTURE ON MPR AND VRT

FRACTURE TYPE	MPR	VRT
ANTERIOR WALL	UN DISPLACED- +++	+
	DISPLACED- +	+++
ANTERIOR COLUMN	+++	+
POSTERIOR WALL	UN DISPLACED- +++	+
	DISPLACED- +	+++
POSTERIOR COLUMN	+	+++
TRANSVERSE	+	+++
T-TYPE	+	+++
TRANSVERSE WITH POSTERIOR WALL	+	+++
BOTH COLUMN	+	+++
ANTERIOR COLUMN WITH POSTERIOR HEMITRANSVERSE	+	+++

TABLE 18

ASSOCIATED FRACTURES ON MPR AND VRT

Findings	VRT	MPR
Joint surface irregularities	+	+++
Fracture extension	+++	+
Intraarticular bone fragments	+	+++
Displacements and incongruities of the fracture fragments	+++	+
Associated fractures of the sacrum and femur	+	+++

TABLE 19

SENSITIVITY OF MPR vs VRT

FRACTURE TYPE	N0. OF FRACTURES	PERCENTAGE	MPR	VRT
ANTERIOR WALL	DISPLACED- 8	16	75%	87.5%
	UNDISPLACED- 7	14	85.7%	71%
ANTERIOR COLUMN	7	14	85.7%	57.1%
POSTERIOR WALL	DISPLACED- 4	8	75%	100%
	UNDISPLACED- 2	4	100%	50%
POSTERIOR COLUMN	2	4	50%	75%
TRANSVERSE	2	4	50%	100%
T-TYPE	4	8	50%	75%
TRANSVERSE WITH POSTERIOR WALL	8	16	62.5%	87.5%
BOTH COLUMN	5	10	60%	80%
ANTERIOR COLUMN WITH POSTERIOR HEMITRANSVERSE	1	2	-	100%
TOTAL	50	100		

DISCUSSION

CT imaging is currently a necessary tool in the evaluation and planning of acetabular fracture treatment. Advances in multidetector-row CT technology and high-speed data processing in the emergency department allow rapid production of high-quality 2D and 3D images for interpretation. The present study was carried out in 50 patients with clinically suspected or known hip fractures admitted in emergency or orthopedics wards of Dayanand Medical College, Ludhiana.

64% (32 cases) in our study were males and 36% (18 cases) were females. The increased percentage of males in our study probably reflects the fact that in Indian society it is the male who is the breadwinner of the family and consequently has to travel more often and hence at more risk to accidental roadside trauma.

The patients ranged from 15-75years, the maximum number of patients were in the age group of 20-40 years (42%) with a mean age of 36.26 yrs and median age being 30 yrs. This reflects the most active age in life, especially about traveling. Hence, most of the people are in this age group. Our results are comparable with those of Ahmed et al [34] (2018), Dias et al [35] (2015), and Marcelo et al (2019). The study by Marcelo et al, stated that acetabular fractures had a bimodal distribution, affecting one extremely young and active patient and one elderly patient. The mean age of patients with acetabular fractures was 39.8 years (SD 13.1 yrs).

Roadside injury due to motor vehicle accidents was the leading cause of pelvic trauma in 37 patients (74%), whereas a fall from height accounted for 13 patients (26%). The high incidence of pelvic trauma (74%) caused by motor vehicle accidents is comparable to the study of Snohiadski et al [36] (2001) and Meir et al (2015). The study by Snohiadski et al reported traffic accidents as a cause of acetabular

fractures in 84% of patients. The authors reported a fall from height as a cause of acetabular fractures in 14% of patients as compared to 26% in our study.

CT is superior to plain radiography in not only confirming or excluding the fractures but also clearly demonstrating whether the fractures are unilateral or bilateral, bilateral involvement of acetabulum was noted in 4 patients on computed tomography.

The most common dislocation of the femoral head associated with pelvic trauma was posterior as seen in 9 patients with anterior dislocation seen only in 5 patients. The high incidence of posterior dislocation in the present study compares well with the study done by Brown et al [37] (2000) who also reported 14 patients of posterior dislocation out of 70 patients included in their study.

The sensitivity of CT is more in the detection of fractures of the quadrilateral plate and roof as the transverse axis of the images allows the precise characterization of the abnormality of the structure, which is not possible with other modalities such as conventional radiography. The overall sensitivity of CT is 100% as compared to 86% in conventional radiography in the detection of these fractures.

The use of 3D surface reformations of complex anatomical structures from sets of contiguous axial CT sections had been discussed by Guy et al (1992), Magid et al [38] (1986), Fishman et al [39] (1989), and Rommens et al [40] (1995). Guy et al even opinionated that time that fracture lines demonstrated on plain radiographs and axial scans are not always apparent on 3D reconstructions.

But now with recent advances in CT, the use of the new three-dimensional CT imaging modalities help classify and plan for treatment of acetabular fractures. The three-dimensional CT reconstructions and CT Stimulated antero-posterior and Judet views of the pelvis were

created by radiologists and radiographers who used a standardized computer workstation and software.

Modern software has improved such that recreated images have better resolution and more options are available for viewing the data. For example, the three-dimensional and simulated views can be rotated 360 degrees in any direction. Also, the femoral head can be subtracted out of the acetabulum, providing the surgeon with an inside view of the pelvis unlike that of any plain radiograph. This approach caused the number of certain types of acetabular fracture patterns to be seen more frequently, such as posterior wall and transverse– posterior wall types.

There are three most complex fracture types particularly both-column, T-type, and anterior column or wall with posterior Hemi transverse which was most difficult to demonstrate on imaging as they had similar kinds of fracture lines and were mostly displaced with few fracture lines which did not characterize in any of the fracture types. These constitute 10 cases (20%) in our study. We found that we were able to correctly classify T- type fractures in 75% of cases and both column fractures in 80% cases on VRT images as compared to 50% and 60% on MPR imaging.

Our study was comparable to the study done by Seebaly et al which found 35% improvement incorrect classification (from 28 to 63%) with trainees when 3D images were added but only 7% (from 85 to 92%) among the experts. Oohashi et al (2006) also mentioned in their study that disagreements tend to occur more frequently in fracture types that have a common fracture component, such as a transverse fracture component (which is common to transverse, T-shaped, and transverse and posterior wall fractures).

However, the study conducted in the year 2019 by Thanat et al concluded that by 3D reconstructions, improvement occurred only in the interpretation of transverse and posterior wall-type fractures but not

in T type, transverse with posterior wall, or both-column fractures. This difference in our and this study could be attributed to the fact that in their study only complex fractures were included and the sample size was small (25 patients).

The other significant finding was found in simpler fractures like the transverse and displaced fractures of anterior and posterior walls which contributed to approximately 14 cases (28%). We found that we could correctly judge these fractures in 11 cases (71.4%) on MPR and 14 cases (92.8%) on VRT images. This was comparable to the study done by Thanat et al (2019) who found greater improvement in interpretation accuracy with 3D in simple types (transverse and posterior wall fractures). They also revealed that 3D images can reveal pelvic fractures from an inside perspective, enhancing visualization of transverse fractures. Seebaly et al also said in their study that with displaced fractures, 3D reconstruction is never a problem.

Another study done by O'Toole (2010) reported accuracy improvement in both simple (transverse type) and complex (posterior column with posterior wall and both-column) fractures.

In our study, we had 9 cases (18%) simple and undisplaced fractures of the anterior and posterior walls which were seen in 8 (89%) of the cases on MPR and only 5 (55.4%) of the cases in VRT. This was explained in the study done by Seebaly et al (2018) which said that smoothening associated with 3D reconstruction is a reality and depends more and more on the software used. Another study was done by Ohashi et al (2006) also showed that subtle fractures can be missed on 3D images.

We had 7 cases of anterior column fractures in our study which constitute 14% of cases. It was found that the boundaries of the anterior column of the acetabulum were complex as the fracture line most often extends superiorly into the iliac wing or less commonly extends towards the anterior inferior iliac spine with disruption of the

iliopectineal line. The fracture is best visualized on sagittal MPR images in 6 cases (85.7%) as compared to the VRT images where we could only classify 4 cases (57.1%). This was comparable to the study done by Gejjer et al (2007) in which anterior column fracture accounted for 4% of all acetabular fractures. The fracture was best visualized on sagittal MPR images. On 3-D images, with or without electronic disarticulation of the femoral head, the fracture line can be seen traversing both the external and internal surfaces of the hemipelvis. The study conducted by Seebaly et al (2018) also showed MPR images to be better in the interpretation of anterior column fractures as compared to VRT images.

Another major observation done with our study was a significant reduction in the interpretation time of acetabular fractures with 3D images as compared to 2D images. Although it requires a few extra minutes to acquire the 3D images, it returns benefits in terms of faster and more accurate interpretation as well as more effective communication among physicians providing patient care. This advantage was comparable to the studies done by Thanat et al (2019), Seebaly et al (2018), Otoole et al (2010). In the study done by Seebaly et al the average time of interpretation were 96 minutes for 2D sets and 47 minutes for 3D sets with the mean gain of 49 minutes.

The other factors that need to be evaluated were joint surface irregularities, fracture extension, intra- articular bony fragments, displacements, and incongruities of the fracture fragments and associated fractures of the sacrum and femur.

Out of the above said the joint surface irregularities, intra-articular bony fragments, and associated pelvic fractures were best seen on MPR images. The thin slices are also necessary to properly evaluate the articular surfaces and search for entrapped intra-articular osteochondral fragments. Whereas the fracture extension lines and displacements were best seen on VRT images. 3-D images are also

very helpful in assessing the misalignment of the major fracture fragments, which may be very difficult to appreciate on axial slices or MPR images.

SUMMARY AND CONCLUSION

The radiological evaluation of hip and acetabulum has been revolutionized by the development of computed tomography and the use of multiplanar reformatting and volume rendering technique because of its fine definition of cross-sectional anatomy and accurate evaluation of pelvic trauma. The present study is comprised of 50 patients of pelvic trauma with clinical suspicion of acetabular fractures presenting to the department of radio-diagnosis. The following conclusion was drawn from our study:-

- The patients from all age groups were involved, the maximum number of patients were in the age group of 20-40 years (42%) with a mean age of 36.26 yrs and median age being 30 yrs.
- Males were seen to be frequently involved in pelvic trauma as compared to females. Males were 64% (32 cases). 36% (18 cases) were females.
- The patient who sustained pelvic trauma due to roadside accidents was 37 patients (74%). Only 13 patients (26%) had a history of falls from height leading to pelvic trauma.
- The most common dislocation of the femoral head associated with pelvic trauma was posterior as seen in 9 patients with anterior dislocation seen only in 5 patients.
- The three most complex fracture types particularly both-column, T-type, and anterior column or wall with posterior Hemi transverse constitute 10 cases (20%) in our study. Out of these, we were able to correctly classify T- type fractures in 75% of cases and both column fractures in 80% cases on VRT images as compared to 50% and 60% on MPR imaging
- In the present study we found that in simpler fractures like the transverse and displaced fractures of anterior and posterior walls which contributed to approximately 14 cases (28%), we

could correctly judge 11 cases (71.4%) on MPR and 14 cases (92.8%) on VRT images.

- We had 9 cases (18%) simple and undisplaced fractures of the anterior and posterior walls which were seen in 8 (89%) of the cases on MPR and only 5 (55.4%) of the cases in VRT
- Another common type of fracture in our study was anterior column fractures which constitute 14% of cases in our study. It was found that due to complex boundaries and extension lines of the anterior column fractures, these were best visualized on sagittal MPR images in 6 cases (85.7%) as compared to the VRT images where we could only classify 4 cases (57.1%).
- Another major observation done with our study was a significant reduction in the interpretation time of acetabular fractures with 3D images as compared to 2D images. Although it requires a few extra minutes to acquire the 3D images, it returns benefits in terms of faster and more accurate interpretation as well as more effective communication among physicians providing patient care.
- Intra-articular bony fragments and associated pelvic fractures were best seen on MPR images. The thin slices are also necessary to properly evaluate the articular surfaces and search for entrapped intra-articular osteochondral fragments.
- The fracture extension lines and displacements were best seen on VRT images.
- 3-D images are very helpful in assessing the misalignment of the major fracture fragments, which may be very difficult to appreciate on axial slices or MPR images
- Most of the fractures in the present study were complex with the involvement of multiple segments of the acetabulum.
- The axial plane of the computed tomography is seen to be the most suitable for the evaluation of the roof and quadrilateral plate with CT showing 100% sensitivity.

From the present study, we conclude that computed tomography is superior to conventional radiographs in evaluating acetabular fractures, the involvement of specific segments of the acetabulum, associated fractures of pelvic bones, and in the detection of intra-articular fragments. CT displays better anatomy of the acetabulum in the axial plane, thereby providing the missing pieces of information and greatly facilitating the classification of acetabular injury.

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CASE I

FIGURE1. Axial and sagittal CT of the undisplaced anterior wall fracture. Volume rendered image shows an undisplaced horizontally oriented fracture line of anterior wall fracture.

CASE II

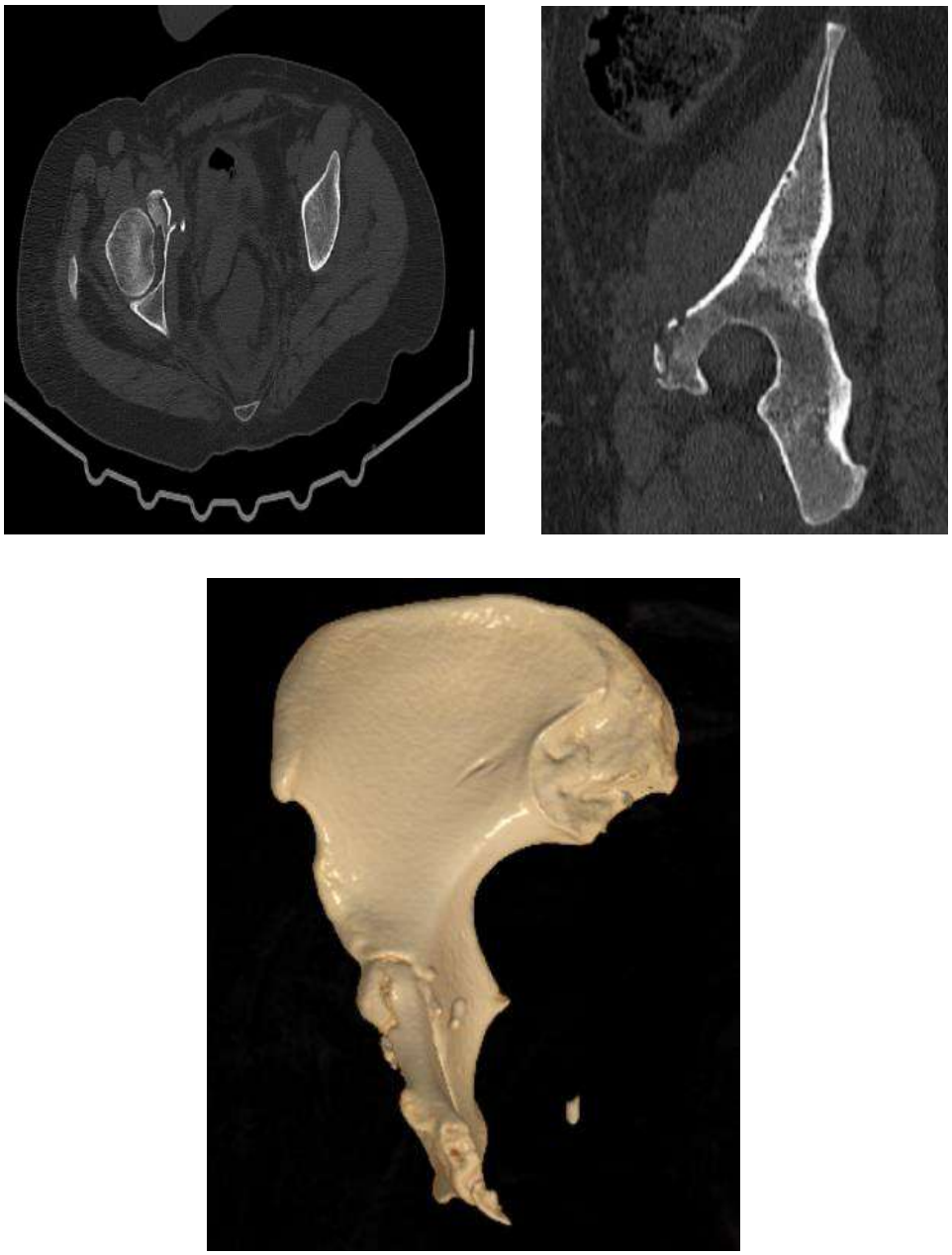

FIGURE2. Axial and sagittal CT of the displaced anterior wall fracture. Volume rendered image shows displaced fracture line and fracture fragments of anterior wall fracture.

CASE III

Figure 3: Sagittal and axial CT of the anterior column fracture showing fractures of the fracture extending from the iliac blade into the roof and involving the anterior wall. 3D volume rendered image shows a vertically oriented fracture separating anterior column from posterior column and sciatic buttress.

CASE IV

FIGURE4. Axial and sagittal CT of the undisplaced posterior wall fracture. Volume rendered image shows an undisplaced fracture line of posterior wall fracture.

CASE V

FIGURE5.Axial and sagittal CT of the displaced posterior wall fracture. Volume rendered image shows displaced fracture line and fracture fragments of posterior wall fracture.

CASE VI

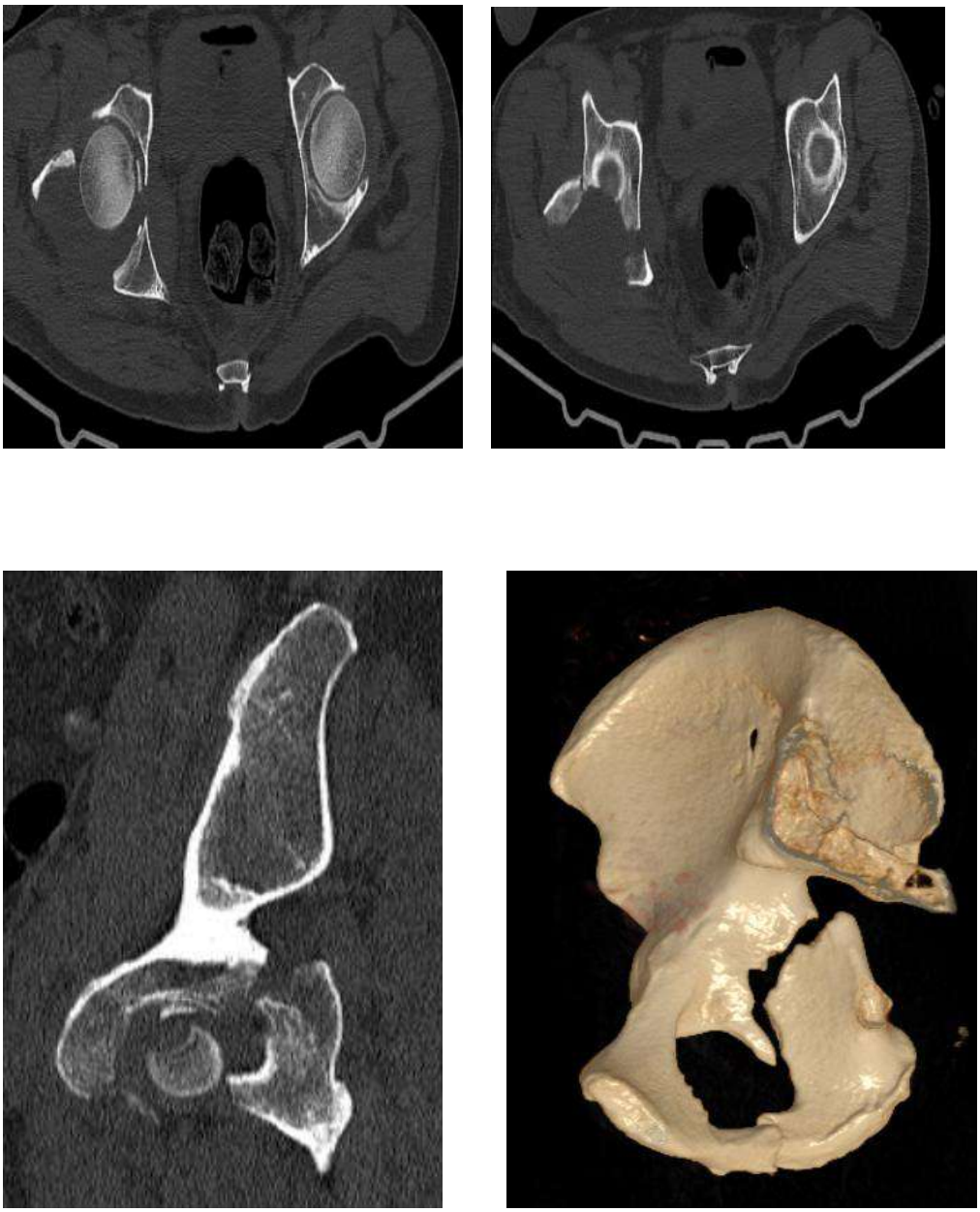

Figure6. Axial and sagittal CT of the posterior column fracture shoing the fracture of the acetabular roof extending posteriorly and terminates at the greater sciatc notch. 3D volume rendered image shows a vertically oriented fracture separating posterior column from anterior column.

CASE VII

Figure7. Axial CT of transverse fracture. Axial and sagittal image at the level of the acetabulum shows the fracture extending in antero-posterior direction and 3D volume-rendered CT image show a horizontally oriented fracture dividing anterior and posterior columns into upper iliac and lower ischiopubic segments.

CASE VIII

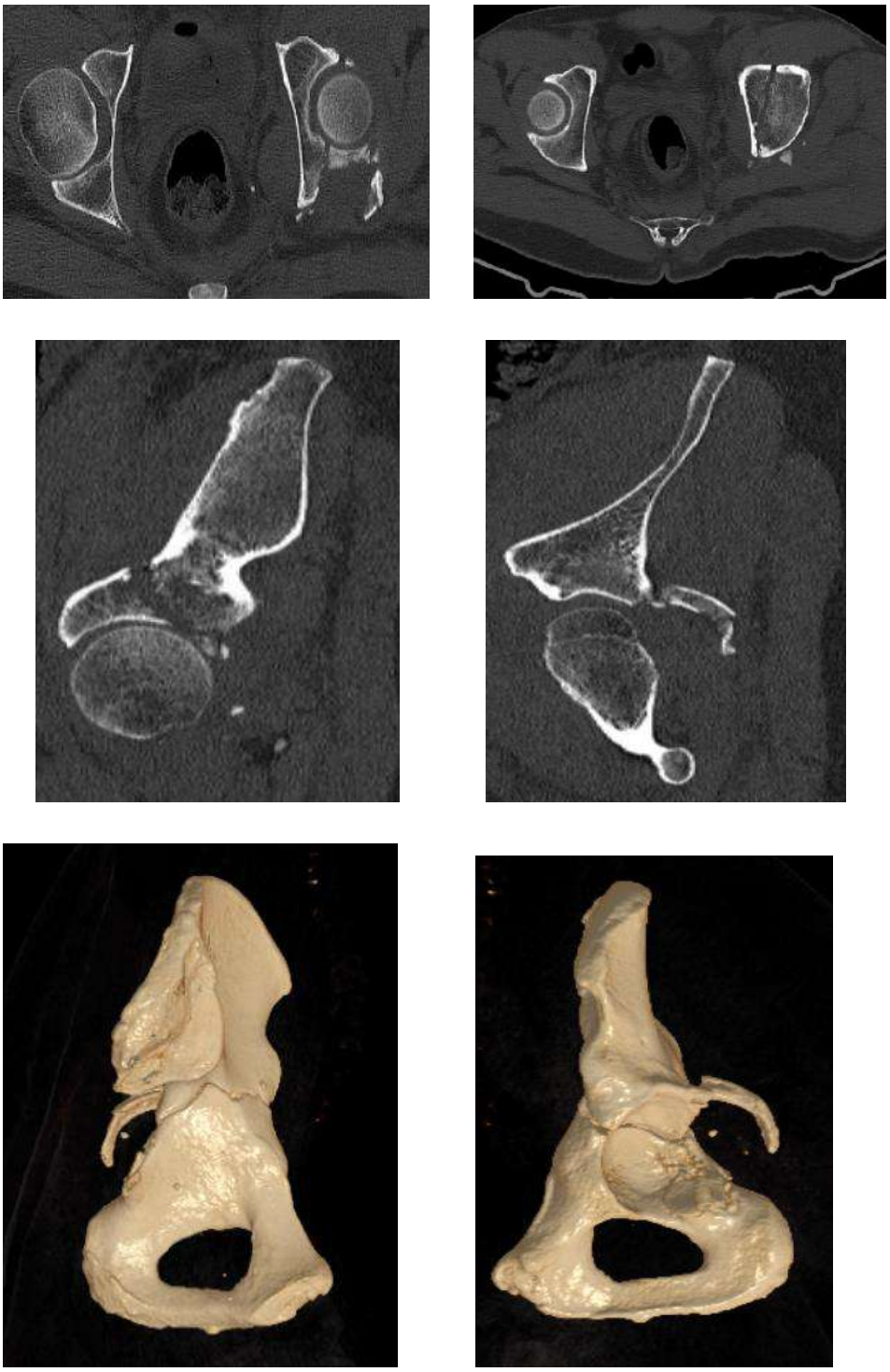

Figure 8. Axial and sagittal CT of transverse with posterior wall acetabular fracture showing fracture extending in antero posterior direction and 3D surface-rendered CT image shows a horizontally oriented fracture dividing anterior and posterior columns into upper iliac and lower ischiopubic segments.

CASE IX

Figure 9. Axial and sagittal CT of T-type acetabular fracture showing fracture extending in antero posterior direction. The stem of the T-shaped fracture extends inferiorly through the acetabular notch and the ischio-pubicramus.

CASE X

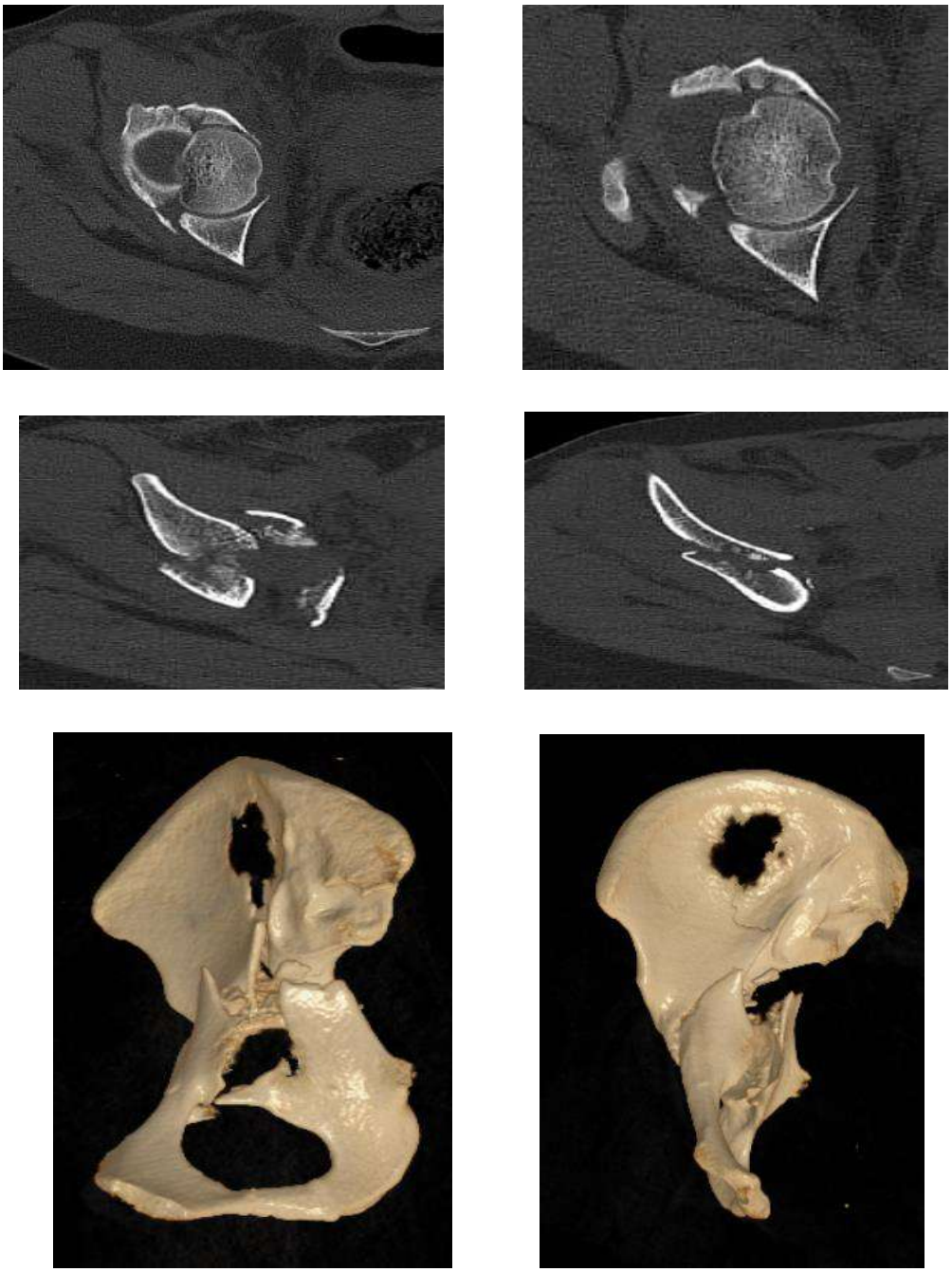

Figure 10. Axial CT of both column fractures. Fracture starts from sciatic buttress involving both anterior and posterior columns. 3D volume-rendered CT image shows a vertically oriented fracture through the quadrilateral surface with fracture line extending into iliac wing and second fracture line extending into greater sciatic notch.

						Findings on Computed Tomography																				Comparison of VRT VS MPR for fracture detection									
						Pattern of acetabular fractures													Associated Fractures				IABF	VRT					MPR					
Sr. No.	Name	Mrd no.	Age	sex	Mode of injury	C	L	U/L	B/L	D	AW	PW	AC	PC	ROOF	QP	S.I	EXT	IB	S	R	FM		JSI	FE	IABF	D	ASS	JSI	FE	IABF	D	ASS
1	PK	802955	26	F	RSA	-	+	+	-	-	+	-	+	-	+	-	-	+	-	+	+	-	-	B	B	-	B	B	A	A	-	A	B
2	AM	848562	47	M	RSA	-	+	+	-	-	+	-	-	-	-	-	-	-	-	+	+	-	-	A	A	-	A	B	B	B	-	B	B
3	AG	890019	52	M	RSA	+	-	-	+	+	-	-	-	-	-	-	+	-	+	+	+	-	-	A	A	A	A	B	B	B	B	B	B
4	KS	752059	66	M	FALL	+	-	+	-	+	+	-	-	-	-	-	+	-	+	+	+	-	-	A	A	A	A	A	B	B	B	B	B
5	MK	838684	50	F	RSA	+	-	+	-	+	+	-	-	+	-	-	+	+	-	+	-	-	+	B	B	A	B	B	A	A	B	A	B
6	DKS	821854	20	F	RSA	-	+	+	-	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	A	-	-	A	A	-	-	-	B
7	PA	646742	52	F	FALL	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	A	-	-	A	-	B	-	-	B
8	JS	923409	56	M	RSA	+	-	+	-	+	+	-	-	+	+	+	+	+	-	-	-	-	+	B	B	A	B	B	A	A	B	A	A
9	AV	303232	59	M	RSA	+	-	+	-	+	+	+	-	-	-	+	+	+	-	-	+	-	+	B	B	A	B	B	A	A	B	A	B
10	JK	680191	52	F	RSA	+	-	+	-	+	+	-	+	-	+	+	+	+	+	+	+	-	+	B	B	A	B	B	A	A	B	A	B
11	JA	746700	41	M	RSA	-	+	+	-	-	+	-	-	-	-	-	-	-	+	+	+	-	-	A	A	-	-	A	B	B	-	B	B
12	NV	805532	29	M	RSA	-	+	+	-	+	-	+	-	-	-	-	+	-	-	-	-	+	-	B	B	-	B	B	A	A	-	A	B
13	AS	824403	36	F	RSA	+	-	+	-	+	+	-	+	-	+	-	+	+	+	-	-	-	+	A	A	A	A	A	B	B	B	B	B
14	SR	841408	35	F	RSA	+	-	+	-	+	-	+	+	+	+	-	+	+	-	-	+	+	+	B	B	A	B	B	A	A	B	A	A
15	JA	759790	25	M	RSA	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	A	A	A	-	A	B	B	B	-	B
16	SS	678886	46	M	RSA	+	-	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-	+	B	B	B	B	B	A	A	A	A	A
17	MK	646385	63	F	RSA	+	-	-	+	+	+	-	-	-	-	-	+	-	-	+	+	-	-	A	A	A	A	A	B	B	B	B	B
18	MN	679565	52	M	RSA	+	-	+	-	+	-	+	-	+	+	-	+	+	-	-	-	-	+	B	B	A	B	-	A	A	B	A	-
19	HS	836836	29	M	RSA	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	A	A	-	A	-	B	B	-	B	-
20	AS	751783	27	M	RSA	-	+	-	+	-	+	-	+	-	+	-	+	+	+	-	+	-	-	A	A	-	-	A	B	B	-	-	B
21	SK	831139	50	M	RSA	+	-	+	-	+	-	+	+	+	+	-	+	+	+	-	-	-	+	B	B	A	B	-	A	A	B	A	-
22	GS	749107	55	M	RSA	+	-	+	-	+	-	+	+	+	+	-	+	+	-	-	-	-	+	B	B	A	B	-	A	A	B	A	-
23	SRS	615007	64	M	FALL	+	-	+	-	+	+	-	-	-	-	-	+	-	-	-	+	-	-	B	B	-	B	-	A	A	-	A	B
24	GU	749204	32	M	RSA	+	-	+	-	+	+	-	-	-	-	-	+	-	-	+	+	-	-	B	B	-	B	A	A	A	-	A	B
25	JS	907182	53	M	FALL	-	+	+	-	+	-	-	-	+	+	+	+	+	-	-	+	-	+	B	B	A	B	-	A	A	B	A	-
26	MS	907927	73	M	FALL	+	-	-	+	+	-	+	+	-	+	-	+	+	-	-	+	-	+	B	B	A	B	-	A	A	B	A	-
27	VK	719951	25	M	RSA	+	-	+	-	+	+	-	+	+	-	+	+	+	+	-	+	-	-	B	B	B	B	-	A	A	A	A	-
28	GU	809371	65	F	FALL	+	-	+	-	+	+	+	+	+	+	+	+	+	+	-	+	-	-	B	B	A	B	-	A	A	B	A	-
29	BMK	816207	58	M	FALL	+	-	+	-	+	+	-	+	-	+	-	+	+	+	-	-	-	+	A	A	A	A	-	B	B	B	B	-
30	SK	681665	36	M	RSA	+	-	+	-	+	-	+	+	+	+	+	+	+	-	+	-	-	+	A	A	A	A	-	B	B	B	B	-
31	BK	644302	21	M	RSA	+	-	+	-	+	+	-	+	-	+	-	+	+	+	-	+	-	-	A	A	A	A	-	B	B	B	B	-
32	KK	685112	18	M	RSA	-	+	+	-	-	+	-	-	-	-	-	-	+	-	+	+	-	-	-	A	-	-	-	-	B	-	-	-
33	SS	907140	42	M	RSA	-	+	+	-	-	+	-	-	-	-	+	-	-	+	-	+	-	-	A	A	-	-	A	B	B	-	-	B
34	BK	644302	21	M	RSA	+	-	+	-	+	+	-	+	-	+	-	+	+	+	-	+	-	-	A	A	A	A	-	B	B	B	B	-
35	RS	730029	30	M	RSA	+	-	+	-	+	+	-	-	-	-	+	+	-	-	-	-	-	+	A	A	A	A	A	B	B	B	B	B
36	PO	891154	28	F	RSA	+	-	+	-	+	+	-	-	-	-	-	+	-	-	+	+	-	-	B	B	-	-	B	A	A	-	-	A
37	MA	885307	50	F	FALL	+	-	+	-	+	+	-	-	-	-	-	+	-	-	-	+	-	-	A	A	-	A	A	B	B	-	B	B
38	PV	717791	36	F	RSA	-	+	+	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	A	-	B	-	-	B
39	VK	692073	67	M	FALL	+	+	+	-	+	+	-	+	-	+	+	+	+	+	-	+	-	-	A	A	A	A	-	B	B	B	B	-
40	SK	645065	60	M	FALL	+	+	+	-	+	+	-	+	-	+	-	+	+	+	-	+	-	-	B	B	-	B	-	A	A	-	A	-
41	DS	911861	54	M	FALL	+	-	+	-	+	-	+	-	-	+	-	-	+	-	-	-	-	+	A	A	A	A	A	B	B	B	B	B
42	MN	851887	26	F	RSA	+	-	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-	+	B	B	B	B	B	A	A	A	A	A
43	LO	810664	24	F	RSA	+	-	+	-	+	+	-	+	+	+	+	-	+	+	+	-	+	-	+	B	B	A	A	-	A	A	B	B	-
44	SA	876011	24	M	RSA	+	-	+	-	+	+	-	+	+	+	+	+	+	+	-	+	-	-	B	B	-	B	-	A	A	-	A	-
45	GU	898468	50	M	RSA	+	-	+	-	+	-	+	+	+	+	-	+	+	-	-	-	-	+	B	B	A	B	-	A	A	B	A	-
46	RG	668626	22	F	RSA	+	-	+	-	+	-	+	-	-	-	-	+	-	-	-	-	-	-	A	-	-	A	-	B	-	-	B	-
47	HK	781198	50	F	FALL	+	-	+	-	+	-	+	+	+	+	+	+	+	-	+	-	-	+	B	B	A	B	A	A	A	B	A	B
48	RA	708505	18	F	RSA	-	-	+	-	-	-	-	+	+	-	+	-	+	-	+	+	+	-	B	B	-	A	A	A	A	-	B	A
49	SR	744206	65	F	RSA	+	-	+	-	+	+	+	+	+	+	+	+	+	-	-	+	-	-	B	B	-	B	-	A	A	-	A	-
50	DI	898325	27	M	FALL	+	-	+	-	+	+	+	+	+	+	+	+	+	-	-	+	-	+	A	B	A	B	-	B	A	B	A	-

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Date 29/11/2019

The Principal,
DMC, Ludhiana.

Subject: **Approval of Plan of Thesis.**

This is to inform you that the Faculty of Medical Sciences in its meeting held on 29.05.2019 has approved the plan of thesis of **Aditi Gupta**, a student of your college for **MD Radio-Diagnosis** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis

Evaluation of acetabular fractures by ct and comparison of multiplanar reformat (mpr) with volumetric rendering techniques (vrt) in fracture detection

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The student has to submit the four copies of thesis (along with PDF format) , to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She must directed to attach a photocopy of this letter with the forwarding letter while submitting thesis to the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic,(if any).

Dr. S P Singh MS(Oph)
Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*
2. *The student may submit the thesis as per the schedule already conveyed i.e for May/June examination 30th Nov of the preceding the year of examination and for Nov/Dec examinations 31st May of the year of examination.*

EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED IN

PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MD

In

RADIODIAGNOSIS

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES

FARIDKOT

November, 2018

DR. ADITI GUPTA

DEPARTMENT OF RADIODIAGNOSIS
DAYANAND MEDICAL COLLEGE AND HOSPITAL
LUDHIANA

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ABSTRACT OF PLAN OF THESIS

Title	EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION
For the degree of	MD (Radiodiagnosis)
Name of the candidate	Dr. Aditi Gupta
Supervisor	Dr. Chandan Kakkar, Assistant Professor, Department of Radiodiagnosis, DMCH, Ludhiana
Co-supervisor(s)	Dr. Kavita Saggar, Professor and Head of Department of Radiodiagnosis, DMCH, Ludhiana Dr. Pankaj Mohindra, Associate Professor, Department of Orthopedics, DMCH, Ludhiana.
Institution	Dayanand Medical College and Hospital, Ludhiana
University	Baba Farid University of Health Sciences, Faridkot

Introduction: Correct recognition, description, and classification of acetabular fractures is essential for efficient patient triage and treatment. The most widely used acetabular fracture classification system among radiologists and orthopedic surgeons is the system of Judet and Letournel. Accurate categorization of acetabular fractures is challenging because of the complex three-dimensional (3d) anatomy of the pelvis. CT provides information on the extent of the fracture and complements conventional radiography in ascertaining the spatial arrangement of the fracture fragments. Also, MPR and VRT reconstructions of CT data have been used as an aid to understanding complex fracture patterns. Correct classification precedes the choice of the surgical approach and serves as the basis for pre-operative planning. By reviewing a VRT image, the surgeon can decide whether or not to operate and which approach to use.

Aim of Study: To evaluate the role of MDCT in assessment of acetabular fractures and to correlate MPR (2D) vs VRT (3D) MDCT findings.

Materials & Methods: The study will be conducted over a period of one year. Consent will be obtained from each patient and relevant detailed history will be elicited from all patients.

Clinical Significance: Comparing a VRT (VOLUME RENDERING TECHNIQUE) image of the fractured acetabulum with a MPR (multiplanar reformat) image are effective ways of arriving at the correct fracture detection and classification

Keywords: Acetabular fractures, MDCT- Multi-Detector Computed Tomography, MPR- Mutiplanar Reformat, VRT- Volume rendering Technique, 2D- 2-Dimensional, 3D- 3-Dimensional.

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Candidate	Co-supervisor	Co-supervisor	Supervisor	Principal

CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION"** exist in the Department of Radiodiagnosis, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate herself under our supervision and guidance.

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BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT

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4	DATE OF ADMISSION OF COURSE	10th May 2018
5	TITLE OF THE TOPIC	EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION

6. BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

The pelvis is a complex three-dimensional (3D) bone that, because of overlap with itself and with the femur, has surfaces that are not easily visible on standard frontal and lateral projections. Most important, fracture nomenclature is complicated and not intuitive. Correct recognition, description, and classification of acetabular fractures is essential for efficient patient triage and treatment. Acetabular fractures may result from high-energy trauma or low-energy trauma in the elderly.

The most widely used acetabular fracture classification system among radiologists and orthopedic surgeons is the system of Judet and Letournel [1-3], which includes five elementary (or elemental) and five associated fractures. The elementary fractures are anterior wall, posterior wall, anterior column, posterior column, and transverse. The associated fractures are all combinations or partial combinations of the elementary fractures and include transverse with posterior wall, T-shaped, associated both column, anterior column or wall with posterior hemitransverse, and posterior column with posterior wall. The most unique fracture is the associated both column fracture, which completely dissociates the acetabular articular surface from the sciatic buttress.

Categorization of acetabular fractures accurately is challenging because of the complex three-dimensional (3D) anatomy of the pelvis, the rarity of certain acetabular fracture variants, and confusing nomenclature. Accurate fracture classification is of great importance for surgeons, especially for beginners, to identify diagnosis, approach, reduction and fixation.[4,5] Fractures are

described relative to the orientation of the acetabulum viewed en face from the lateral side, whereas, in the anatomic position, the acetabulum is tilted inferiorly and anteriorly, making its appearance at radiography and planar computed tomography (CT) nonintuitive relative to the nomenclature.

For example, although the superior pubic ramus is superior, when viewing the acetabulum en face it is anterior. Furthermore, transverse fractures of the acetabulum are predominantly transverse in the acetabular plane but are actually sagittal oblique (with the medial aspect superior to the lateral aspect) in the anatomic plane. Initial radiographic evaluation in trauma patients is frequently suboptimal and limited to anteroposterior (AP) views.

The stability of the pelvic ring is determined by clinical and radiographic means.[6,7] However, fractures have been "underdiagnosed" by plain radiographic findings. The appropriate surgical approach is chosen depending on the classification and the site of the main dislocation so that a correct diagnostic evaluation of the fracture is made.[8-10] Currently, CT is routinely performed to aid preoperative planning in patients with acetabular fractures. Multiplanar two-dimensional axial CT images delineate the acetabular fractures and its extensions better than plain radiographs. Computed Tomography (CT) has become a necessary adjunctive study that, compared with conventional radiography, provides an improved demonstration of intraarticular fragments, joint surface incongruities, femoral head and sacral fractures. Use of Multiplanar Two- And Three-dimensional CT Images has proved helpful for the detailed analysis of acetabular fractures. CT provides information on the extent of the fracture and complements conventional radiography in ascertaining the spatial arrangement of the fracture fragments

Detailed analysis of acetabular fractures, especially with multiplanar two-dimensional CT and with three-dimensional CT, improves detection of joint surface irregularities, fracture extension, intraarticular bone fragments, displacements and incongruities of the fracture fragments, and associated fractures of the sacrum and femur.

Volumetric rendering is a new approach to three-dimensional (3D) imaging that overcomes many of the drawbacks of currently available surface-rendering systems. The fast computing architecture and large memory of this system allow rapid generation of a series of high-quality 3D images in each plane of rotation that can be viewed as independent static images or as an animated real-time video loop. Editing to remove the normal contralateral hemipelvis enhances appreciation of acetabular abnormalities. Every pixel of CT data is preserved, allowing representation of both soft tissue and bone as translucent overlap. The presentation of data also allows detection of subtle abnormalities and features and minimizes the artifact generation common in surface rendered images.[11]

Rapid prototyping, also known as 3D printing (3DP), has been used for preoperative planning, intraoperative assistance, and as an tactile feedback educational tool through direct creation of the patient-specific fracture.[12-14]

6.2 REVIEW OF LITERATURE

In a study conducted by Robert o'toole et al in 2005, they studied if Computed Tomographic (CT) scans improve the ability to classify acetabular fractures in comparison with plain radiographs. Four different image sets for each patient were evaluated: image set A- Judet view plain radiographs plus axial view CT scans; image set B- Judet view plain radiographs alone; Image set C- three-dimensional CT reconstructions; and image set D- CT simulated Anteroposterior and Judet views of the pelvis. The 300 Image sets were viewed in random order by four orthopaedic trauma fellowship trained surgeons who independently recorded a diagnosis. A gold standard diagnosis was determined by group consensus. They concluded that in contrast to previous reports in the literature, the accuracy of plain radiographs alone was less than the accuracy of CT scans. In terms of diagnosis, the interobserver reliability was also worse for plain radiographs alone.[15]

In another study conducted by Holger Keil et al in 2018 on acetabular fractures, the assessment of reduction and implant placement has limitations in conventional 2D intraoperative imaging. 3D imaging offers the opportunity to acquire CT-like images and thus to improve the results. However, clinical experience shows that even 3D imaging has limitations, especially regarding artifacts when implants are placed. The purpose of this study was to assess the difference between intraoperative 3D imaging and postoperative CT, regarding reduction and implant placement. Twenty consecutive cases of acetabular fractures were selected with a complete set of intraoperative 3D imaging and postoperative CT data. The largest detectable step and the largest detectable gap were measured in all three standard planes. These

values were compared between the 3D data sets and CT data sets. Additionally, possible correlations between the possible confounders age and BMI and the difference between 3D and CT values were tested. The mean difference of largest visible step between the 3D imaging and CT scan was 2.0 ± 1.8 mm (0.0–5.8, p = 0.02) in the axial, 1.3 ± 1.4 mm (0.0–3.7, p = 0.15) in the sagittal and 1.9 ± 2.4 mm (0.0–7.4, p = 0.22) in the coronal views. The mean difference of largest visible gap between the 3D imaging and CT scan was 3.1 ± 3.6 mm (0.0–14.1, p = 0.03) in the axial, 4.6 ± 2.7 mm (1.2–8.7, p = 0.001) in the sagittal and 3.5 ± 4.0 mm (0.0–15.4, p = 0.06) in the coronal views. A positive correlation between the age and the difference in gap measurements in the sagittal view was shown (rho = 0.556, p = 0.011). Intraoperative 3D imaging is a valuable adjunct in assessing reduction and implant placement in acetabular fractures but has limitations due to artifacts caused by implant material. This can lead to missed malreduction and impairment of clinical outcome, so postoperative CT should be considered in these cases.[16]

In one of the studies done by Zhenfei Huang et al, published in 2018, on three-dimensional printing model improves morphological understanding in acetabular fracture learning: A multicenter, randomized, controlled study which showed conventional education, results in unsatisfactory morphological understanding of acetabular fractures, due to lack of three-dimensional (3D) details and tactile feedback of real fractures. Virtual reality (VR) and 3D printing (3DP) techniques are widely applied in teaching. The purpose of this study was to identify the effect of physical model (PM), VR and 3DP models in education of morphological understanding of acetabular fractures. Participants

were equally and randomly assigned to the PM, VR and 3DP learning groups. Three-level objective tests were conducted to evaluate learning, including identifying anatomical landmarks, describing fracture lines, identifying classification, and inferring fracture mechanism. Four subjective questions were asked to evaluate the usability and value of instructional materials. Generally, the 3DP group showed a clear advantage over the PM and VR groups in objective tests, while there was no significant difference between the PM and VR groups. 3DP was considered to be the most valuable learning tool for understanding acetabular fractures. The findings demonstrate that 3DP modelling of real fractures is an effective learning instrument that can be used to understand the morphology of acetabular fractures and promote subjective interest.[17]

Another similar study was published in 2006 by Kenjirou Ohash et al, to retrospectively evaluate interobserver agreement for Letournel acetabular fracture classification with radiography alone and multidetector Computed tomography (CT) and to retrospectively assess whether standard Judet views lead to a change in the classification; which included 101 imaging studies performed in 99 patients (78 male, 21 female; mean age, 43 years; age range, 15–86 years) with acetabular fractures. Two musculoskeletal radiologists independently classified the fractures with radiography alone and multidetector CT alone. Multiplanar reformatted and three-dimensional (3D) CT images were reviewed at a computer workstation. Readers were shown radiographs at the end of multidetector CT image reading to see if this would change the multidetector CT–based classification. Values were calculated to assess interobserver agreement. For surgically treated patients, the McNemar

test was used to compare the accuracy of readers classifications. The reference standard was a combination of preoperative radiographic and multidetector CT image findings and intraoperative findings. Interobserver agreement was moderate (0.42) with Radiography and substantial (0.70) with multidetector CT. Multidetector CT classification was changed in two cases (one case for each reader) after standard Judet views were added. In 73 surgically treated patients, agreement with the surgeons' classification was higher with multidetector CT than with radiography ($P < .01$ for one reader, $P < .06$ for the other reader). There is a substantial interobserver agreement for Letournel acetabular fracture classification with multiplanar reformatted and 3D multidetector CT images. Standard Judet pelvic radiographs add little information for changing the multidetector CT classification.[18]

In a study conducted in 2007 by Mats Geijer et al, on imaging of the acetabulum in the era of multidetector Computed tomography which illustrated that understanding and classification of these rare injuries using radiography can be difficult and are much facilitated by the addition of Computed tomography (CT). MDCT with MPR and 3-D reconstructions is an indispensable imaging tool in the detection and work-up of acetabular fractures before and after treatment. The CT examination should be performed with thin axial slices to allow for near-isotropic imaging. The thin slices are also necessary to properly evaluate the articular surfaces and search for entrapped intra-articular osteochondral fragments. A slice thickness of 2 mm or less reconstructed at 1 mm or smaller interval gives good results. In polytrauma patients, where a pelvis CT has been performed, it is necessary using the raw data, to reconstruct axial slices thin enough to allow for good

MPR and 3D reconstructions, which should then be sent to a dedicated workstation, where secondary reconstruction is performed.[19]

Acetabular fractures are complex and difficult to classify. Although the Judet–Letournel classification is designed to increase the understanding of acetabular fractures, it remains prone to error when using conventional medical imaging. We hypothesize that three-dimensional (3D) printing, as a new diagnostic imaging tool, will lead to an increased understanding and knowledge of acetabular fractures and an optimal surgical approach. Digital data (DICOM) of 20 acetabular fractures were converted into 3D files [standard tessellation language (STL) data]. These STL files were used to prepare 3D prints of life-size hemipelvic models with acetabular fractures. Seven senior trauma surgeons specializing in pelvic and acetabular surgery, 5 young fellowship trained trauma surgeons, 5 senior surgical residents, 5 junior surgical residents, and 5 interns classified 20 acetabular cases using X-ray/two-dimensional (2D) computed tomography (CT), 3D reconstructions, and 3D printed models according to the Judet–Letournel classification. Furthermore, all junior and senior surgeons were instructed to evaluate their surgical approach and the positioning of the patient during operation. Time to classify each case was recorded. Calculations were done using Fleiss' j statistics. Only slight and fair interobserver agreements for senior surgeons (j = 0.33) and interns (j = 0.16) were found when using X-ray/2D CT. However, 3D printed models showed moderate and substantial interobserver agreements for senior surgeons (j = 0.59), junior surgeons (j = 0.56), senior surgical residents (j = 0.66), junior surgical residents (j = 0.51), and interns (j = 0.61). Compared with X-ray/2D CT, the interobserver agreement regarding

the surgical approach for junior surgeons using 3D printed models increased by j = 0.04 and j = 0.23, respectively. Except for the interns, a significant time difference for classification was found between X-ray/2D CT and 3D CT and 3D printed models for junior and senior surgical residents and junior and senior surgeons ($p < 0.001$). 3D printing is of added value in the understanding, classification, and surgical evaluation of acetabular fractures. We recommend the implementation of 3D printed models in trauma surgery training.[20]

6.3 AIMS AND OBJECTIVES OF THE STUDY

1. Evaluation of acetabular fractures by Computed tomography.
2. Comparison of multiplanar reformat (MPR) with volumetric rendering techniques (VRT) in fracture detection.

7. MATERIALS AND METHODS

7.1 Source of Data

The study will include both outdoor and indoor patients with acute pelvic trauma being referred to the department of Radiodiagnosis, Dayanand medical college and hospital for Multidetector Computed Tomography.

7.2 METHOD OF COLLECTION OF DATA

The study will be conducted over a period of one year. Consent will be obtained from each patient and relevant detailed history will be elicited from all patients.

Before starting the MDCT study, the procedure will be explained to the patient in his/her vernacular language to allay the fear and anxiety and written informed consent will be taken

INCLUSION CRITERIA

- The subject population will include patients of any age of both sexes suspected clinically or on the basis of other investigations, including plain radiography, to have acute acetabular fracture(s).

EXCLUSION CRITERIA

- Pathological fractures
- Patients who do not give consent for the study

TECHNIQUE OF IMAGING

MDCT in all patients included in this study will be carried out on Somaton definition and 128 slice CT machine by Siemens Germany Std with a gantry rotation speed of 0.5 second ,tube current of 100-350 mA , reconstruction increment of 1.0 mm and slice thickness of 1 mm in the

Department of Radiodiagnosis and Imaging, Dayanand Medical College and Hospital, Ludhiana.

STUDY DESIGN

This is a longitudinal, prospective study.

OUTCOME

Analyzing the MDCT findings of acetabular fractures and comparing Multiplanar Reformat (MPR) with Volumetric Rendering Techniques (VRT) in fracture detection.

STASTICAL ANALYSIS:

Data will be described in terms of range; mean ±standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. Sensitivity, specificity, positive and negative predictive values, accuracy of method and its confidence interval (95% CI) will be also calculated. A probability value (p value) less than 0.05 was considered statistically significant. All statistical calculations were done using SPSS (Statistical Package for the Social Science) SPSS 21 version statistical program for Microsoft Windows.

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

No

7.4 HAS ETHICAL CLEARANCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Attached herewith

8. LIST OF REFERENCES

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PPROFORMA

- SECTION A : Bio-data and Vitals
- SECTION B : History and examination
- SECTION C : MPR findings
- SECTION D : VRT findings
- SECTION E : MPR vs VRT Correlation
- SECTION F : Conclusion for the case

SECTION A : BIO-DATA and Vitals

Patient's Name: Date of Admission:

Age of patient:

Address:

MRD/CR No: Contact No:

Admission No: Nature of Admission:

Consultant:

Vitals-

Blood Pressure: Pulse Rate:

SECTION B : History and examination

- History of any trauma, falls. Past history of any similar complaints. Examination-
- Inspection- Redness, swelling, any external injury, range of motion, numbness, limb weakness, alignment of hip joint, any pelvic tilt, patient able to walk or not.
- Palpation- area of tenderness, warmth, range of motion (passive)

Signature of Candidate **Signature of Supervisor**

SECTION C and D : CT findings

CT helps in demonstration of

- Detailed analysis of acetabular fractures
- Joint surface irregularities
- Fracture extension
- Intraarticular bone fragments
- Displacements and incongruities of the fracture fragments
- Associated fractures of the sacrum and femur.

Signature of Candidate **Signature of Supervisor**

INFORMED PATIENT CONSENT

Date: _____

I.....D/o, W/o, S/o..... .....am willing to participate in the study **"EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

.....
Signature of the Witness

Name:

.....
Signature of the patient

Signature of Candidate

Signature of Supervisor

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____

निवासी _____

इस शोधकार्य **"EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION"** में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह जोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

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गवाह के हस्ताक्षर

नाम:

_____

रोगी के हस्ताक्षर/अंगूठे का निशान

नाम:

_____

अन्वेषक के हस्ताक्षर

_____

विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫ਼ਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

"EVALUATION OF ACETABULAR FRACTURES BY CT AND COMPARISON OF MULTIPLANAR REFORMAT (MPR) WITH VOLUMETRIC RENDERING TECHNIQUES (VRT) IN FRACTURE DETECTION" ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

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ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____

ਪਤਾ _____

_____
ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____

ਪਤਾ _____

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ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

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ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ